SCIENTIFIC AGRICULTURE

VOLUME 27 JULY, 1947 No. 7

A STUDY OF SOME SOLONETZIC SOIL COMPLEXES IN SASKATCHEWAN[1]

BY C. F. BENTLEY AND C. O. ROST[2]

[Received for publication March 25, 1947]

Solonetz and related intrazonal soils are common to steppe and semi-desert regions in Russia (24)[3]. In North America these soils occur predominantly in the arid and semi-arid regions comprising the brown, chestnut and chernozem soil zones although complex podzolic-solonetzic soils have been reported in Saskatchewan (23) and Alberta (20).

The intrazonal soils solonchak, solonetz, solodized solonetz, and solod are considered to represent a sequence of related soils which frequently occur as soil complexes. A solonchak is a saline soil which results from an accumulation of water soluble salts. Following the formation of the solonchak by salinization a change in local moisture conditions may result in the gradual removal of salts. According to de Sigmond (6), if sodium occupies not less than 10-15 per cent of the exchange complex there will be an appreciable dispersive effect on the soil when the total salt content is down to 0.10-0.15 per cent or less. The exchangeable sodium peptizes the soil colloids so that they fill the soil interstices sufficiently to greatly reduce percolation. There is, at the same time, some hydrolysis of sodium from the exchange complex with the result that the soil becomes alkaline in reaction. This removal of salts and change in reaction has been called desalinization and alkalinization or by the single term "solonization". Such soils are called solonetz.

Solodization is the next process involved. Exchangeable sodium and peptized colloids are largely removed from the A horizon by eluviation with the result that a very distinctive morphology develops. The A_2 horizon is usually platy and vesicular in structure and typically has a gray colour very similar to that of A_2 horizons in podzolized soils. In most cases the individual platelets are darker coloured on their lower surface than on their upper surface. The A horizon is lighter textured than the B horizon into which the dispersed colloids have been moved. The B horizon becomes a dense, compact, highly colloidal, intractable, more or less impervious clay-pan layer. During dry periods vertical cracks form in this clay-pan horizon and a columnar structure develops. Under the peptizing influence of sodium, organic matter from the upper part of the profile moves into the B horizon giving it a darker colour than the A horizon above it. Such a soil has been designated as a solodized solonetz.

[1] Contribution from Department of Soils, University of Saskatchewan, and Division of Soils, University of Minnesota, published with the approval of the Director of the Minnesota Agricultural Experiment Station as Paper No. 2327 of the Journal Series.

[2] Formerly Assistant Professor of Soils, University of Saskatchewan, now Assistant Professor of Soils, University of Alberta, and Professor of Soils and Chief, Division of Soils, University of Minnesota, respectively.

[3] Figures in parenthesis refer to literature cited page no. 313.

As the sodium hydrolyzes from the exchange complex in the A horizon of a solonetz an acid reaction develops. Sesquioxides are eluviated downward into the B horizon and the A horizon becomes more siliceous. The hydrolysis is most intense at the point of contact between the A and B horizons and as a result, the rounded tops of the columns of the B_1 horizon are coated and flaked with powdery, almost white siliceous material which also sifts down into the cracks between the columns. As the hydrolysis and leaching continue, the thickness of the A horizon increases and the thickness of the highly dispersed solonetzic B horizon is correspondingly reduced. Gradually, the columnar structure of the B horizon becomes less distinct; the round tops gradually disappear and the columns tend to break up into nut-like fragments. This process continues until the profile loses its solonetzic characteristics and becomes friable to a considerable depth. The soil is then called a solod.

DIFFERENCES OF OPINION CONCERNING SOLONETZIC SOILS

These processes and soils have been described by several soil scientists (5, 10, 11, 18, 24, 25, 29). However, there have arisen some differences of opinion concerning the characteristics of solonetzic soils. To a considerable extent this difficulty is the result of different concepts of the essential characteristics of these soils as described by some of the outstanding European soil scientists. One group of these European soil scientists have taken the view that solonetzic soils are distinguished by certain morphological characteristics and to them the possessing of certain chemical characteristics is secondary. A second group consider chemical characteristics to be the most important ones in deciding whether or not a soil is a solonetz. Many Russian solonetz soils apparently satisfy both the chemical and morphological descriptions given by these groups. In Russia differences of opinion have arisen when a soil satisfied one description but not the other.

These divergent views have resulted in some uncertainty in North America as to what constitutes a solonetz. Most of the uncertainty concerning these soils in America is a result of a tendency to consider a soil to be a true solonetz only if it meets both the chemical and morphological characteristics. In North America many soils possessing the morphological characteristics of a solonetz but having high proportions of exchangeable magnesium and relatively low amounts of exchangeable sodium in the B horizon have been reported and there has been considerable uncertainty as to whether these soils should be considered to be true solonetz

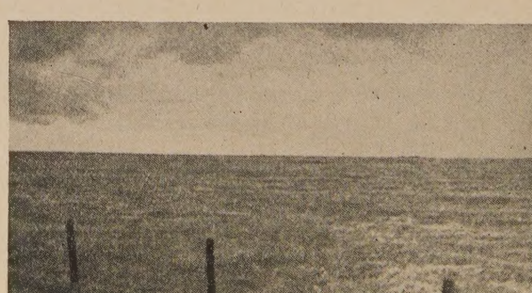

FIGURE 1. General view showing landscape of a complex of non-eroded and eroded solodized solonetz. Note the numerous small depressions, known locally as "burn-outs", where the solodized *A* horizon has been largely removed by erosion.

(8, 16, 30). In recent years there have been reports of similar morphological solonetz high in exchangeable magnesium and low in exchangeable sodium in Russia (9, 15, 26, 33, 34, 37, 38).

In North America there has been some divergent use of terms applied to solonetz and related soils. This is particularly true of the term solodized solonetz which is used rather widely (7, 8, 17, 23, 30) to refer to soils in the intermediate stage between solonetz and solod although the authors have not encountered any statement or discussion as to when a solonetz becomes a solodized solonetz or when the latter becomes a solod. The term solodized solonetz is also used in Europe as Joffe (15) presents some Gedroiz data for a "solodized solonetz from western Siberia".

The object of the investigation reported here is to provide information regarding solonetzic and related intrazonal soils as they occur in Saskatchewan presenting data concerning them and discussing their occurrence under differing topographic and moisture conditions as set forth below.

DEFINITIONS OF TERMS

In view of the general lack of uniformity in the use of the terms solonetz, solodized solonetz, and solod it appears desirable to define the terms as used in the present paper.

The term solonetzic will be used to refer to all soils possessing in any part the clay-pan B horizon which characterizes these soils.

The term solonetz will apply to those solonetzic soils which do not possess a grayish, leached, platy structured, acidic (*i.e.* solodized) A_2 horizon which is distinguishable by colour from the darker A_1 and B horizons. As in some cases a visibly distinguishable A_2 horizon does not develop this term will not apply to solonetzic soils with more than six inches of friable, platy structured acidic A horizon.

The term solodized solonetz will apply to those solonetzic soils possessing a solodized A_2 horizon which is visibly distinguishable or which possess six inches or more of friable, platy structured, acidic A horizon. It is realized that this definition will include as solodized solonetz many soils which in the past have been called solonetz. However, the definition includes in this group only profiles showing definite solodization.

The term solod will apply to soils having no remnant of a solonetzic B horizon but showing either (or both) morphological or chemical characteristics of a solodized soil as described.

Thus used, these terms will largely, if not entirely, preserve the Russian meanings. For example, such usage would be in accord with the labelling of Ivanova's sketch shown on page 464 by Joffe (15). It is hoped that these definitions will aid in a clearer understanding of these soils as they exist in North America.

TOPOGRAPHIC RELATIONSHIPS

Since the climate of the Canadian prairie provinces is very similar to that of the Russian steppes it is logical to expect close resemblance between their zonal and intrazonal soils. Studies of intrazonal soils of the solonchak, solonetzic and solod group in Western Canada have shown them to be very

similar to the descriptions of corresponding Russian soils. Ellis and Caldwell (8), MacGregor and Wyatt (20), Mitchell and Riecken (22), and Mitchell *et al.* (23) have ably described and discussed these soils in the Prairie Provinces. Extensive areas of solonetzic soils are found in Alberta and Saskatchewan where their occurrence is closely correlated with certain geological formations (1, 23). The parent material of these solonetzic and related soils is predominantly thin glacial drift which is usually somewhat less calcareous than the parent material of most Saskatchewan soils; this thin drift is underlain by Cretaceous marine shales which are devoid of lime and which frequently contain appreciable amounts of pyrite. Studies of solonetzic soils in Saskatchewan have shown them to be typical from the morphological point of view. However, on the average they have a rather low content of exchangeable sodium and a high content of exchangeable magnesium in the B_1 horizon. For the most part, the exchange complex of these soils has been characterized by a calcium to magnesium ratio of more than one in the A horizon while this ratio was less than one in the B_1 horizon in most cases. On the average, sodium occupied slightly over 10 per cent of the total exchangeable bases in the B_1 horizon of these soils.

A certain topographic relationship for the various profile members of solonetzic soil complexes has been mentioned and sketched as shown by Joffe (15). In this relationship solod soils are found in the lowest topographic position, while solodized solonetz, solonetz and normal zonal soils—in that order—are found with progressive rise to higher positions.

In Saskatchewan there are two topographic relationships between the member profiles of solonetzic soil complexes. The relationship described above occurs quite commonly. In the second relationship the solonetz (or a solonchak) is found in the lowest topographic position followed by the solodized solonetz, the solod and the normal zonal soil—in that order—on rise to higher ground. Topographically, this second sequence of profiles is in reverse order to the one first described. This second case seems to contravene the idea that the solod develops in the moister locations where more leaching occurs as has been stated to be the general case (6, 24). However, it appears that in such instances there is a locally higher water table which inhibits leaching in the lowest topographic position. The solodized solonetz and solod profiles therefore develop in higher topographic positions where there is more actual leaching. MacGregor and Wyatt (20) state that in Alberta solonetzic soils are sometimes found on the upper slopes of local elevations. The fact that Saskatchewan solonetzic soils occur as complexes is in agreement with conditions in Russia where Glinka (11) states that under normal conditions solonetz occur as a soil complex—especially in the brown soil zone.

SAMPLING AND ANALYTICAL METHODS

The work of this study consists of two phases—field study and laboratory study. In September, 1943, 12 profiles were examined and sampled at 3 sites in the Weyburn area of south-eastern Saskatchewan. The surface geological deposit in this area has been classified as modified bedrock shale with thin drift in places (23). In Saskatchewan and Alberta, soils developed on such geological material are predominantly solonetzic. An area of this type was selected for a study of solonetzic and related soils because in these

provinces such soils are much less common on other types of geological material. The present paper reports the studies made on 10 profiles taken at two of these locations. At each site a careful study of the micro-relief was made and the profiles were carefully described and photographed. The profile sampling was done by horizons except where the depth of a particular horizon exceeded 10 inches in which case the layer was sampled in 2 sections of approximately equal thickness. In the laboratory the samples were air dried and after hand grinding with a mortar and pestle they were stored in quart sealers.

The laboratory determinations made on the samples were: exchangeable bases including exchangeable hydrogen, base exchange capacity, pH, mechanical analysis, base soluble silica, inorganic carbon, amount and nature of salts (if any), and in most cases total nitrogen in the upper horizons of the profiles.

The base exchange leaching was done by a convenient method which may be considered a modification of Baver's method (2). Ten grams of soil with filter paper and an aliquot of normal ammonium acetate were shaken for 2 hours. The contents of the flask were transferred to a Buchner funnel and were leached with ten successive increments of the leachant employing a total volume of 400 cc. of normal ammonium acetate. The leachate was treated as recommended by Schollenberger and Dreibelbis (32) after which the basic cations were determined by standard methods.

Special procedures were adopted for calcareous samples and for those containing water soluble salts. For the determination of exchangeable calcium and magnesium in calcareous samples a 70 per cent alcoholic solution of 0.2 N potassium chloride adjusted to pH 7 as recommended by Chapman and Kelley (4) was used. Saline samples were leached with carbon dioxide free water until free of water soluble salts before they were leached for determination of exchangeable calcium and magnesium. This procedure was not satisfactory for determination of exchangeable sodium in saline samples as that cation was largely removed from the exchange complex by the water leaching. This fact is well illustrated by the data of Table 1 which presents results of exchangeable sodium determinations after a salt free soil high in exchangeable sodium had been leached with varying amounts of water. Exchangeable sodium was therefore taken to

TABLE 1.—EFFECT OF WATER LEACHING ON EXCHANGEABLE NA IN A SOIL

Sample No.	Treatment before base exchange leaching	M.E. exchangeable Na per 100 gms. of soil	
		Duplicate results	Average
4	Samples moistened	6.67 6.60	6.63
4	Samples leached with 3 litres of H_2O	2.64 2.60	2.62
4	Samples leached with 7.5 litres of H_2O	1.02 1.32	1.17

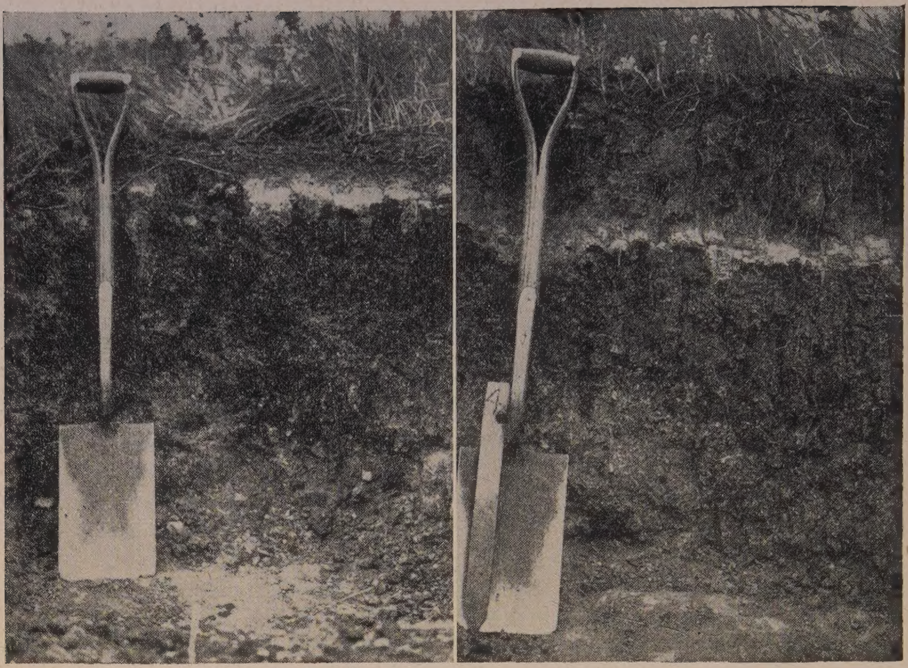

FIGURE 2. *Profile 7.*—A solodized solonetz only slightly solodized. There is a thin *A* horizon above the gray-capped, rather flat columns of the *B* horizon.

FIGURE 3. *Profile 8.*—(Taken 18 feet up slope from *Profile 7*). A solodized solonetz with a deep leached layer. The *B* horizon with its round-topped columns and hard nutty aggregates stands out in sharp contrast to the friable *A* and *C* horizons.

be the difference between total sodium displaced by leaching saline samples with normal ammonium acetate and total water soluble sodium extracted using a 1 to 5 soil to water ratio. No special procedure was necessary for determination of exchangeable potassium in saline samples as the water soluble salts did not contain measurable amounts of this element. It will be observed that base exchange capacity data obtained by summation and by determination vary somewhat, particularly in the lower horizons of the profiles. Such variation is typical of base exchange capacity data—especially in calcareous horizons containing salts.

Exchangeable hydrogen was determined by a modification of Maehl's method (21) using a Coleman model 3C pH electrometer. Base exchange capacity was determined by Peech's (27) method and base soluble silica by the method used by Rost and Maehl (31). Other determinations were made by standard methods.

The 10 profiles reported in this study occurred in two locations in the vicinity of the city of Weyburn in south-eastern Saskatchewan. The surface geological deposit in this area has been described as modified bed rock shales with thin drift in places (23). Complexes of solonetzic and related soils predominate on this geological deposit in the Weyburn area. A general view of the landscape is shown in Figure 1.

The two locations, their profiles and data concerning them will be described and presented before the profiles are discussed individually.

RESULTS OF FIELD AND LABORATORY STUDIES

Site I. A Location Where the Solod Profile Occurs in the Depressional Position

The topography at Site I is gently undulating and the area has been mapped as Estevan loam. The Estevan Association consists of medium textured solonetzic soils, with solodized solonetz and solod profiles predominating, occurring on boulder clay deposits modified by underlying shales. This site is typical of locations where in proceeding from the top of a knoll to a slight depression, part way down the slope, one encounters the three soil groups of the grassland regions of Saskatchewan[1]. At this particular site the sequence of profiles found when proceeding from the crest of a knoll down a slope of about 4 per cent was calcareous zonal, normal zonal, weakly developed solonetz, and solodized solonetz. This topographic relationship of the profiles involved is similar to the one sketched by Ivanova as shown by Joffe (15). However, the solodization here has not proceeded as far as in Ivanova's sketch and a solodized solonetz, not a solod, occupied the lowest topographic position in the sequence. In the upper topographic position of the sequence the solonetzic development is less marked than in her sketch. Nearby in a position affording better drainage a solod much like those described by de Sigmond (6) was sampled.

Six profiles, referred to as Profiles 1, 2, 3, 4, 5, and 6 were sampled at this site. Brief profile descriptions follow and analytical data concerning them are given in Table 2. As the site was not adjacent to a highway, the reaction of the surface sample of the solonetzic profiles has not been affected by calcareous dusts and so it is normally acidic.

PROFILE 1. A calcareous zonal profile taken on the top of a knoll.

This profile was limy to the surface with a weakly prismatic structure in the lower A and upper B horizon. The lower B horizon was massive structured and had much mottling due to lime and salts. The parent material was friable glacial till, buffish brown in colour and having some mottling due to lime and salts.

* * *

PROFILE 2. A normal Weyburn soil 25 feet down slope from Profile 1.

This profile appeared to be quite similar to Profile 1 but did not contain free lime in the surface 12 inches of the profile. This profile is typical of normal prismatic stuctured profiles dominant in the grassland region of Saskatchewan.

* * *

PROFILE 3. A weakly developed solonetz 17 feet down slope from Profile 2.

This profile was very similar in appearance to Profile 2 with the exception that the B_1 horizon was a brighter reddish dark brown. The prismatic structured units of the B horizon were harder than those of Profile 2 and they tended to fragment into nut-like units rather than to granulate. Since no visual evidences of solodization were apparent the profile is probably a solonetz which has not been strongly solonized.

---

1. The columnar-cloddy group, the alkali-solonetzic group and the high lime group. (Soil Survey Report No. 12, University of Saskatchewan.)

TABLE 2.—ANALYTICAL DATA FOR PROFILES AT SITE I, HAVING SOLOD PROFILE IN A DEPRESSION

Lab. No.	Depth	Horizon	pH	0.002 mm. clay per cent	N_2 per cent	Base sol. silica per cent	Per cent of total bases					Base exch. cap.*	
							H	Ca	Mg	K	Na	By sum.	By deter.
Profile 1.—A calcareous zonal profile on the top of a knoll													
52	0– 2″	A_1	7.6	24	.334	0.97	—	61.6	25.7	10.0	2.7	26.1	23.2
53	2– 7″	A_2	7.8	29	.272	0.54	—	63.7	28.6	4.2	3.5	26.0	22.9
54	7–12″	B_1	8.0	26	.210	0.44	—	58.3	34.1	2.8	4.8	24.9	19.7
55	12–17″	B_1	8.0	27	.203	0.52	—	38.3	49.5	2.2	10.0	27.5	20.8
56	17–21″	B_2	8.1	29	—	0.43	—	29.6	57.6	0.8	12.0	26.6	19.1
58	34–48″	C_2	8.2	26	—	0.39	—	28.6	53.0	1.6	16.8	24.5	17.1
Profile 2.—A normal zonal profile 25 feet down slope from Profile 1													
59	0– 3″	A_1 and A_2	6.7	25	.530	5.60	10.0	66.8	17.5	5.2	0.5	38.9	32.3
60	3– 8″	B_1	6.7	23	.195	0.66	21.5	53.9	20.5	3.4	0.7	29.3	23.5
61	8–13″	B_1	6.8	26	.143	0.63	9.2	61.4	25.0	3.1	1.3	22.8	19.2
62	13–21″	B_2	7.9	19	—	0.21	—	59.4	35.3	2.3	3.0	13.3	19.8
64	34–48″	C_2	8.3	25	—	0.38	—	29.4	55.5	2.7	12.4	22.6	15.3
Profile 3.—A weakly developed solonetz 17 feet down slope from Profile 2													
65	0– 3″	A_1	6.7	19	.428	5.73	10.4	64.5	18.5	6.0	0.6	31.8	29.3
66	3– 4″	A_2	6.4	16	.185	1.48	14.5	54.2	26.0	6.4	1.3	22.7	18.6
67	4– 9″	B_1	5.8	30	.148	0.59	13.4	51.3	30.5	3.7	1.1	26.9	23.5
68	9–13″	B_1	6.3	25	.119	0.45	8.0	57.7	29.3	2.9	1.3	23.9	22.1
69	13–18″	B_2	7.9	24	—	0.18	—	63.3	29.3	3.7	3.7	18.8	12.2
70	18–23″	B_3	7.9	26	—	0.33	—	48.7	42.8	3.7	4.8	18.9	12.6
72	34–48″	C_2	8.2	28	—	0.33	—	28.4	54.4	2.5	14.7	23.8	15.4

* M.E. per 100 gm. of air dry soil.

TABLE 2.—ANALYTICAL DATA FOR PROFILES AT SITE I, HAVING SOLOD PROFILE IN A DEPRESSION—*Concluded*

Lab. No.	Depth	Horizon	pH	0.002 mm. clay per cent	N_2 per cent	Base sol. silica per cent	Per cent of total bases					Base exch. cap.*	
							H	Ca	Mg	K	Na	By sum.	By deter.
Profile 4.—A solodized solonetz with well developed round tops 13 feet down slope from Profile 3													
73	0– 3″	A_1	5.9	18	.328	4.96	24.9	48.6	16.6	8.7	1.2	24.1	22.7
74	3– 6″	A_2	5.5	21	.148	1.30	42.3	31.7	22.5	1.4	2.1	14.2	14.0
75	6– 8″	A_3	6.0	18	.065	0.57	29.4	23.5	38.2	2.9	6.0	10.2	8.4
76	8–16″	B_1	7.2	32	.085	0.62	—	16.8	67.9	3.6	11.7	19.6	19.4
77	16–22″	B_2	8.2	38	—	0.35	—	67.8	22.2	1.3	8.7	23.0	17.2
78	22–28″	B_3	8.3	28	—	0.52	—	53.2	37.6	1.4	7.8	21.8	16.5
80	37–48″	C_2	8.1	28	—	0.58	—	33.9	51.2	1.8	13.1	22.9	16.4
Profile 5.—A solodized solonetz in an advanced state of development 20 feet down slope from Profile 4													
81	0– 3″	A_1	6.3	13	.566	7.97	15.8	58.1	18.2	7.1	0.8	37.9	32.9
82	3– 8″	A_2	5.8	22	.147	0.98	27.8	35.8	24.1	9.2	3.1	16.2	15.4
83	8–12″	A_3	5.8	24	.107	0.53	19.2	27.6	39.9	6.9	6.4	20.3	19.5
84	12–16″	B_1	6.5	25	.121	0.46	8.9	21.9	56.5	5.1	7.6	23.7	20.5
85	16–20″	B_2	7.0	25	.084	0.40	—	25.7	59.1	6.8	8.4	24.9	19.1
86	20–28″	B_3	8.3	27	—	0.26	—	62.9	24.7	1.6	10.8	19.4	13.0
88	37–48″	C_2	8.1	21	—	0.58	—	30.7	48.0	4.8	16.5	18.8	11.7
Profile 6.—A solod taken in a low position 90 feet from Profile 5													
89	0– 3″	A_1	5.7	24	.778	9.41	24.7	50.4	15.6	8.7	0.6	46.2	34.5
90	3–12″	A_2	5.7	14	.086	4.09	34.5	38.2	19.4	6.1	1.8	16.5	11.5
92	12–22″	A_3	6.0	16	.058	0.81	15.1	53.6	22.3	7.3	1.7	17.9	14.2
93	22–30″	B_1	6.2	30	.063	0.66	9.6	55.1	28.5	5.7	1.1	28.1	23.1
94	30–38″	B_2	7.0	31	—	0.56	—	60.8	33.2	4.8	1.2	25.0	21.9
95	38–48″	C_1	7.8	24	—	0.51	—	67.2	28.2	3.4	1.2	17.4	15.3

* M.E. per 100 gm. of air dry soil.

Profile 4. A solodized solonetz with round tops 13 feet down slope from Profile 3.

The morphology of this profile was very similar to that of Profile 2. The parent material of this profile was very much the same as that of Profiles 1, 2 and 3.

* * *

Profile 5. A solodized solonetz taken 20 feet down slope from Profile 4.

This profile had a solodized A horizon 1 foot thick and the B horizon was less distinctive than that of Profile 4. The round-topped columns were disintegrating into nut-like units in a manner similar to that illustrated by Figure 4. The parent material was similar to that of other profiles at this site.

* * *

Profile 6. A solod taken in a low position 90 feet from Profile 1.

This profile had 22 inches of leached friable A horizon above a heavy mottled B horizon which was rather friable. It was underlain at 48 inches by coarse sand.

Site II. A Location Where the Solod Profile Occurs in a Well-Drained Position

The topography at this site is moderately undulating and the soil in this area has been mapped as a mixture of Weyburn loam with Trossachs and Estevan clay loams. The Weyburn Association consists of medium textured soils developed upon boulder clay in the dark brown (chestnut) soil zone. The Estevan Association consists of medium textured solonetzic soils, with solodized solonetz and solod profiles predominating, occurring on boulder clay deposits modified by underlying shales. The Trossachs Association is similar in parent material to the Estevan Association but Trossachs profiles are usually less solodized.

The site is typical of locations where a poorly drained low area has solonetzic soils fringing it which gradually grade to normal zonal soils as elevation increases. Many such locations have an area of solonchak soil at the lowest point and fringing this are found in order: solonetz, solodized solonetz, solod, and then the normal zonal profiles. As the season of 1943 when the samples were collected followed a year of high precipitation, most of these solonchak areas were under water and so it was not possible to sample such a location.

Four profiles, which will be referred to as Profiles 7, 8, 9 and 10, were sampled at Site II. Figures 2, 3, 4 and 5 are photographs of these profiles. A topographical sketch, Figure 6, shows the positional relationship of the profiles sampled at this site. Average slope where these profiles were taken was about 3 per cent. Analytical data concerning them are given in Table 3. Dust from an adjacent highway probably accounts for the slightly alkaline reaction of the surface samples.

TABLE 3.—ANALYTICAL DATA FOR PROFILES AT SITE II, HAVING SOLOD PROFILE IN A WELL-DRAINED POSITION

Lab. No.	Depth	Horizon	pH	0.002 mm. clay per cent	N_2 per cent	Base sol. silica per cent	Per cent of total bases					Base exch. cap.*	
							H	Ca	Mg	K	Na	By sum.	By deter.
Profile 7.—A solodized solonetz only slightly solodized													
22	0– 3″	A_1	7.0	19	.407	5.58	8.3	52.9	27.8	9.2	1.8	32.7	30.2
23	3– 4″	A_2	6.2	15	.246	5.08	25.1	34.0	30.7	4.6	5.6	21.5	18.9
24	4– 8″	B_1	5.7	36	.132	1.26	23.8	27.6	34.0	3.2	11.4	31.5	20.9
25	8–16″	B_2	6.9	47	.096	0.85	6.7	41.7	42.4	2.5	6.7	40.1	29.2
26	16–22″	B_3	8.0	27	—	0.42	—	61.1	28.8	2.5	7.6	19.8	15.5
28	35–48″	C_2	7.7	28	—	0.57	—	56.3	33.2	2.8	7.7	18.2	12.9
Profile 8.—A solodized solonetz with a deep leached layer and well developed round tops 18 feet up slope from Profile 7													
29	0– 3″	A_1	7.3	18	.354	4.49	—	52.5	24.1	22.4	1.0	29.5	26.7
30	3– 8″	A_2	5.4	19	.162	2.65	28.2	31.4	30.1	5.4	4.9	22.3	14.9
31	8–11″	A_3	5.8	17	.101	1.34	21.7	30.1	39.2	4.2	4.8	16.6	10.8
32	11–14″	B_1	7.3	47	.148	0.87	2.4	12.3	74.6	4.7	6.0	38.2	32.3
33	14–20″	B_2	7.8	41	.099	0.60	—	12.0	77.3	4.9	5.8	32.6	27.9
34	20–26″	B_3	7.9	31	—	0.38	—	70.8	19.2	4.4	5.6	31.8	22.7
36	37–48″	C_2	7.6	19	—	0.60	—	60.4	23.3	4.1	12.2	11.2	11.0
Profile 9.—A solodized solonetz in an advanced stage of development 10 feet up slope from Profile 7													
37	0– 3″	A_1	7.5	19	.340	4.58	—	58.3	26.9	13.7	1.1	27.1	26.0
38	3– 9″	A_2	5.4	21	.189	2.36	41.9	30.7	20.0	4.1	3.3	21.5	16.0
39	9–10″	A_3	5.3	13	.093	0.87	37.5	18.7	29.7	3.9	10.2	12.8	9.5
40	10–12″	B_1	6.1	39	.137	0.56	12.6	10.7	63.0	5.5	8.1	30.8	27.0
41	12–16″	B_1	7.1	43	—	0.50	5.3	12.1	71.5	3.8	7.3	33.9	29.7
42	16–19″	B_2	7.8	36	—	0.52	—	17.3	71.6	3.8	7.3	28.9	25.4
43	19–26″	B_3	8.0	20	—	0.45	—	73.6	20.2	2.5	3.7	24.3	18.8
45	37–48″	C_2	7.9	23	—	0.53	—	40.2	42.8	4.5	12.5	20.1	13.6
Profile 10.—A solod 10 feet up slope from Profile 9													
46	0– 4″	A_1	7.4	20	.365	3.13	—	57.7	28.9	12.3	1.1	27.7	28.3
47	4– 9″	A_2	5.6	22	.184	2.09	35.0	38.6	18.8	5.8	1.8	22.3	17.4
48	9–15″	A_3	5.4	28	.152	1.03	25.7	46.2	20.6	5.5	2.0	25.3	22.2
49	15–22″	B_1	6.7	34	.111	0.51	4.3	60.0	30.4	3.9	1.4	27.9	24.9
50	22–35″	B_2	7.7	27	—	0.44	—	72.6	22.4	3.5	1.5	20.1	14.8
51	35–48″	C_1	8.0	24	—	0.47	—	55.1	39.5	2.7	2.7	14.7	11.5

* M.E. per 100 gm. of air dry soil.

TABLE 4.—ANALYTICAL DATA CONCERNING SALT AND LIME CONTENT OF PROFILES REPORTED. (SEE TABLES 2 AND 3 FOR DEPTHS AND pH'S OF HORIZONS)

Horizon	Total water soluble salts per cent	Water soluble salts*				CO_3 as per cent $CaCO_3$
		Ca	Mg	Na	SO_4	
Profile 1.—A calcareous zonal profile						
A_1	—	—	—	—	—	3.1
A_2	—	—	—	—	—	4.1
B_1	0·03	0.9	1.0	0.3	1.9	6.8
B_1	0.26	1.1	3.2	1.5	3.2	5.0
B_2	1.31	4.9	19.2	2.3	19.1	6.0
C_2	0.80	1.3	9.7	2.7	12.4	12.0
Profile 2.—A normal zonal profile						
A_1 and A_2	—	—	—	—	—	—
B_1	—	—	—	—	—	—
B_1	—	—	—	—	—	—
B_2	0.20	1.8	1.2	0.8	2.6	8.0
C_2	0.58	0.8	4.4	4.1	8.3	9.5
Profile 3.—A weakly developed solonetz						
A_1	—	—	—	—	—	—
A_2	—	—	—	—	—	—
B_1	—	—	—	—	—	—
B_1	0.05	0·4	1.0	0.3	0.3	0.3
B_2	0.08	0.6	0.9	0.5	0.9	20.0
B_3	0.17	0.7	1.7	1.6	2.1	12.0
C_2	0.66	0.8	5.1	5.1	8.7	13.5
Profile 4.—A solodized solonetz with well developed round tops						
A_1	—	—	—	—	—	—
A_2	—	—	—	—	—	—
A_3	—	—	—	—	—	—
B_1	0.23	0.3	1.6	3.0	2.7	0.5
B_2	1.90	12.2	15.7	6.9	28.0	12.1
B_3	1.71	8.8	14.8	7.7	25.4	17.0
C_2	0.72	1.6	5.8	5.0	10.7	12.0
Profile 5.—A solodized solonetz in an advanced stage of development						
A_1	—	—	—	—	—	—
A_2	—	—	—	—	—	—
A_3	—	—	—	—	—	—
B_1	0.20	0.6	1.9	2.5	2.1	—
B_2	0.53	1.5	5.6	3.4	7.2	0.5
B_3	1.70	11.0	13.9	5.9	25.3	17.0
C_2	0.48	0.9	3.7	4.3	6.6	11.0
Profile 6.—A solod profile						
A_1	—	—	—	—	—	—
A_2	—	—	—	—	—	—
A_3	—	—	—	—	—	—
B_1	—	—	—	—	—	0.2
B_2	—	—	—	—	—	1.5
C_2	—	—	—	—	—	21.0

* M.E. per 100 gm. of air dry soil.

TABLE 4.—ANALYTICAL DATA CONCERNING SALT AND LIME CONTENT OF PROFILES REPORTED. (SEE TABLES 2 AND 3 FOR DEPTHS AND pH'S OF HORIZONS)—*Continued*

Horizon	Total water soluble salts per cent	Water soluble salts*				CO_3 as per cent $CaCO_3$
		Ca	Mg	Na	SO_4	
Profile 7.—A solodized solentz only slightly solodized						
A_1	—	—	—	—	—	0.8
A_2	—	—	—	—	—	—
B_1	—	—	—	—	—	—
B_2	1.47	5.5	11.3	8.7	20.3	—
B_3	1.46	9.0	10.0	6.2	20.2	9.9
C_2	0.33	2.6	2.6	0.9	4.5	16.0
Profile 8.—A solodized solonetz with well developed round tops						
A_1	—	—	—	—	—	0.9
A_2	—	—	—	—	—	—
A_3	0.16	0.2	0.6	1.7	2.0	—
B_1	1.00	0.7	10.0	7.0	15.6	—
B_2	1.04	0.9	10.4	7.7	15.4	0.3
B_3	2.12	12.9	15.9	7.8	30.1	4.4
C_2	0.73	8.2	4.1	0.7	9.3	17.0
Profile 9.—A solodized solonetz in an advanced stage of development						
A_1	—	—	—	—	—	0.9
A_2	—	—	—	—	—	—
A_3	—	—	—	—	—	—
B_1	0.41	0.3	2.9	4.5	5.6	—
B_1	0.68	0.4	6.0	6.4	9.2	—
B_2	1.33	1.6	15.5	8.4	19.9	0.4
B_3	1.98	12.4	16.2	7.2	28.6	6.6
C_2	0.44	1.9	3.1	2.8	5.3	17.0
Profile 10.—A solod profile						
A_1	—	—	—	—	—	0.9
A_2	—	—	—	—	—	—
A_3	—	—	—	—	—	—
B_1	—	—	—	—	—	0.8
B_2	—	—	—	—	—	20.0
C_1	—	—	—	—	—	20.0

* M.E. per 100 gm. of air dry soil.

CLASSIFICATION OF PROFILES AND DISCUSSION OF THEIR DATA

On the basis of the classification made the following types of profile are represented: calcareous zonal (Profile 1); normal zonal hard columnar (Profile 2); weakly developed solonetz (Profile 3); solodized solonetz (Profiles 4, 5, 7, 8, and 9), and solod (Profiles 6 and 10). The characteristics of these profile types will be discussed briefly.

The calcareous zonal profile (No. 1) effervesces to the surface and contains soluble salts from the B_1 horizon down. The pH, texture, base exchange capacity, base soluble silica, amount of nitrogen and lime all show that there has been little eluviation and weathering in the profile. Situated on top of the knoll a considerable part of the precipitation has been lost as run-off and this has restricted leaching. As will be observed for other profiles at this location the ratio of exchangeable calcium to magnesium is

less than one in the lower part of the profile. In the course of developing suitable analytical methods it had been found that the parent material samples at this site had a high content of magnesium carbonate. This high proportion of exchangeable magnesium in the parent material is undoubtedly related to its high content of magnesium carbonate. This profile shows no morphological or chemical characteristics of a solonetzic soil.

The normal zonal soil profile represents the dominant member of the Weyburn Association. The pH's for the profile are very slightly lower but not significantly different to others reported for the Weyburn Association (22, 23). The profile is not a highly weathered one but is more mature than Profile 1. This statement is supported by the fact that salts and lime are in the lower part of the profile and by the data for base soluble silica, base exchange capacity, texture, and exchangeable cations. There is a low content of exchangeable sodium in the profile and the ratio of exchangeable calcium to magnesium is greater than one in the upper part of the profile.

Profile 3 closely approaches the suggested definition of a solonetz. The profile possesses many of the characteristics of the normal zonal soil but the upper part of the B horizon shows some morphological features of a clay-pan solonetzic B horizon. The chemical data reflect somewhat the solonetzic features shown morphologically. The upper part of the profile is more acid in reaction than was Profile 2, and the base exchange capacity data show that eluviation and illuviation have definitely occurred. The data for clay contents are also rather different to those of Profile 2. The sodium content of the upper horizons is slightly higher and the exchangeable magnesium occupies a larger portion of the exchange complex than in Profile 2. These are definite signs of solonization.

Profiles 4, 5, 7, 8, and 9 have been classified as solodized solonetz soils. The data for these profiles show considerable variations which are reflected by the profile descriptions and photographs. These data and descriptions show clearly that these 5 profiles represent various stages in the process of solodization. Progressively greater solodization occurs with the profiles in the order 7, 4, 8, 9 and 5. Collectively the solodized solonetz profiles have been leached to a greater depth, have more base soluble silica in the upper part of the profile, have a more obvious difference between the A and B horizons, have a higher content of exchangeable sodium in the B_1 horizon, and have a greater accumulation of exchangeable magnesium in the upper part of the B horizon, than have the foregoing profiles. These characteristics are a result of the process of solonization and solodization.

The solod profiles, numbers 6 and 10, are quite different in chemical characteristics to the foregoing profiles. As a result of solodization, the solonetzic characteristics of the B horizon have disappeared, this horizon now having more normal amounts of exchangeable sodium and magnesium. Unlike profiles previously discussed, soluble salts are not found to the depths sampled. Moreover, their morphological characteristics are quite different to those of the other profiles. The depth of leaching as well as the amount of base soluble silica and exchangeable potassium indicate these two profiles to be more mature and weathered than the previously discussed

FIGURE 4. *Profile 9.*—(Taken 10 feet up slope from *Profile 8*). A solodized solonetz in an advanced stage of development. The solonetzic characteristics of the *B* horizon are much less intense than in *Profile 7*.

FIGURE 5. *Profile 10.*—(Taken 10 feet up slope from *Profile 9*). A solod which is probably in the process of reconstruction. The solonetzic characteristics of the *B* horizon have disappeared and the deep *A* horizon has excellent development of platy structure.

profiles. The base exchange capacity differences, while fairly large, are not nearly as great as were those for solodized solonetz profiles. There is not an accumulation of exchangeable sodium or magnesium in the B horizon and calcium is the dominant exchange ion throughout the profile. These characteristics are in agreement with those attributed to solod soils.

DISCUSSION

Morphologically the profiles of solonetzic soils reported here conform very satisfactorily to the descriptions of these soils given by recognized authorities (11, 17, 24). Chemically these profiles show no sharp variation from the classical descriptions of solonetzic soils with the exception that they possess a high proportion of exchangeable magnesium in the upper B horizon and some of them are rather low in their content of exchangeable sodium.

The exchangeable sodium content of soils which have been considered to be solonetzic has been much discussed in North America. Several workers (8, 16, 22, 30, 36) have reported solonetzic soils not possessing the 10-15 per cent of exchangeable sodium which de Sigmond (6) considers necessary for solonization. Most of these soils have been solodized, at least to some extent, and therefore a low content of exchangeable sodium does not seem sufficient reason for not classifying them as solonetzic soils

TABLE 5.—EXCHANGEABLE CA, MG, AND NA REPORTED FOR THE B_1 HORIZON OF VARIOUS SOLONETZIC AND SOLONETZ-LIKE SOILS IN NORTH AMERICA AS WELL AS THOSE REPORTED BY THE AUTHORS

Reported by	No. of profiles	Exchangeable cations as % of total replaceable bases					
		Ca%		Mg %		Na %	
		Aver.	Range	Aver.	Range	Aver.	Range
Kelley (16) California	7	36	49–27	51	67–40	12	18–5
Rost (30) Minnesota	6	24	33–15	70	76–62	4	6–2
Rost and Maehl (31) Minnesota							
1. Least solodized profiles	5	24	—	64	—	3·5	—
2. Intermediate solodization	6	58	—	29	—	0·9	—
3. Most solodized profiles	6	50	—	29	—	0·8	—
MacGregor (19) Alberta							
Profiles Ca/Mg less than 1	5	31	42–36	51	57–39	18	35–10
Profiles Ca/Mg more than 1	19	62	73–45	32	45–24	6	14–1
Stalwick (35) Saskatchewan	5	32	50–14	56	70–37	12	21–8
Janzen (13) Saskatchewan	3	25	43–7	49	65–37	25	37–11
Mitchell and Riecken (22) Sask.	2	18	19–17	74	76–72	8	(Na + K)
	Profile No.	Ind.		Ind.		Ind.	
Authors Saskatchewan							
Profiles Ca/Mg less than 1	6	36		45		15	
	7	13		76		6	
	8	13		74		9	
	4	17		68		12	
	5	21		65		10	
			36–13		76–45		15–6
Profiles Ca/Mg more than 1	10	62		28		7	
	1	58		34		5	
	2	69		27		1	
	3	59		35		1	
			69–58		35–27		7–1

since de Sigmond (6) and Gedroiz (10) have mentioned that in the process of solodization much of the exchangeable sodium may be displaced or removed.

The high proportion of exchangeable magnesium in the upper B horizon has been frequently reported and discussed in North America (13, 16, 20, 28, 30, 31). There have been similar reports and discussions in Russia (9, 15, 26, 33, 34, 37, 38). In order to study and compare data concerning proportions of exchangeable sodium, magnesium and calcium in some solonetzic soils reported by various workers in North America, the authors have prepared Table 5. These data show that a majority of the profiles concerned have an exchangeable calcium to magnesium ratio of less than 1.0 in the B_1 horizon. However, in very few instances did these profiles have any A horizon layers where this ratio was less than 1.0. Moreover, those A horizon layers where this ratio was less than 1.0 were A_2 or A_3 samples and such layers would constitute the portion of the A

horizon which had most recently been a part of the B horizon. Magnesium which accumulated on the exchange complex of these layers when they were part of the B horizon has probably been only partly replaced as yet. Therefore, an exchangeable calcium to magnesium ratio of less than 1.0 is not characteristic of A horizon samples but is found in a majority of B_1 horizons of the solonetzic soils compared in Table 5. The data of Rost and Maehl (31), MacGregor (19) and the authors show that, when their profiles are divided into groups, those profiles with the largest proportion of exchangeable sodium in the upper B horizon also have the largest proportion of exchangeable magnesium. A relationship between the amounts of exchangeable sodium and magnesium in solonetzic soils is thus suggested.

The work of Riecken (28) affords a possible explanation of this relationship between the amounts of exchangeable sodium and magnesium. He determined the amount of calcium and magnesium adsorbed by a colloid from solutions of different reactions containing equivalent amounts of these two cations and he found that below approximately pH 8 more calcium than magnesium was adsorbed while above that pH more magnesium than calcium was "adsorbed". By reference to the solubility product of magnesium hydroxide Riecken calculated that under the conditions of his experiment magnesium ions could begin to precipitate out as magnesium hydroxide between approximately pH 8 and 9. This would indicate that if a soil, or a particular horizon, had a pH above approximately 8 it would be possible for magnesium hydroxide to accumulate there due to precipitation. If subsequently the pH of this soil or soil horizon was lowered, the magnesium hydroxide would again become soluble and could to a considerable extent replace adsorbed cations previously present thus producing an exchange complex which for a time would be dominated by magnesium. Some of Riecken's data strongly support the probability of precipitation of magnesium in some form later removed during his base exchange leaching.

Supporting evidence for this theory is to be found in the work of Gracie *et al.* (12). They describe a type of soil deterioration characterized by the development of black alkali spots where the soil is high in exchangeable sodium, calcium carbonate and acid soluble magnesium. They suggest that, under the water-logged condition in these spots, sulphates in the irrigation water are reduced by *Microspira desulphuricans* and in the process alkaline conditions are produced in the soil. It is suggested that the alkalinity depresses the solubility of calcium and magnesium salts and causes the precipitation of these cations. They state these soils are quite similar to solonetz.

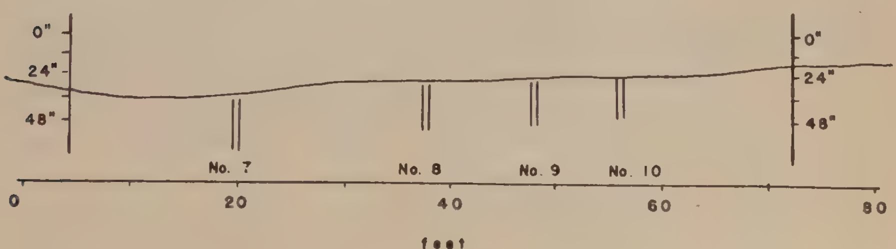

FIGURE 6. Sketch showing relationship of profiles to relief at Site II.

Clarke (5) also makes a statement which lends support to the suggestion that insoluble magnesium compounds may accumulate in alkaline soil horizons. He is of the opinion that magnesite may form as a result of precipitation and suggests that this probably results from the mingling of magnesium sulphate and sodium carbonate in solution.

If magnesium ions are precipitated from solution in alkaline soil horizons, it is logical that such precipitation would occur in the B horizon since Glinka (11) states that this is the most alkaline horizon in solonetz soils. It seems to the authors that this explanation of the high content of exchangeable magnesium in the upper B horizons of solonetzic soils in no way contravenes the generally accepted theory concerning evolution and development of these soils.

Another very similar explanation of the high content of exchangeable magnesium in the upper B horizon of solonetzic soils may be based on the work of Breazeale (3). He showed that when a calcareous soil, the pH of which is between 7 and 8, is leached with a mixture of calcium and magnesium salts, accumulation of magnesium carbonate in the soil results due to the following reaction:

$$CaCO_3 + Mg^{++} \longrightarrow MgCO_3 + Ca^{++}$$

Subsequent leaching of such a soil with carbonated waters would remove any remaining calcium carbonate before removing the magnesium carbonate. Eventually leaching carbonated waters would dissolve the magnesium carbonate and the magnesium ions would then have an opportunity to displace other adsorbed ions in the soil. The development of a soil with an exchange complex dominated for a time by magnesium would be a probable result of such reactions.

de Sigmond (6) gives some of Glinka's data for total analysis of a solonetz as well as some of his own data concerning the hydrochloric acid extract of a Hungarian solonetz. These data show that the magnesium oxide content of the B_1 horizon was higher than that of horizons immediately below it. Glinka (11) also shows this type of data. In one case the magnesium oxide content of the B_1 horizon is more than three times as high as the content of calcium oxide. Pankov and Shavryguin (26) point out that as solonetzosity of soils increases so does the exchangeable magnesium content of the B_1 horizon. They also state that as solodization proceeds there appears to be a gradual increase in the magnesium content of the exchange complex in the upper B horizon to a certain point and that thereafter the content of exchangeable magnesium decreases. The statement of Ellis and Caldwell (8) concerning the exchangeable calcium to magnesium ratios of Manitoba soils is in agreement with this suggestion of Pankov and Shavryguin (26). These statements and facts would seem to support the suggestion that magnesium is precipitated in the B_1 horizon after solonization has taken place.

The proposed explanations have the merit of in no way altering any of the classical theories concerning the evolution of solonetzic soils and permit the identification of solonetz and related soils on purely morpho-

logical characteristics. Another merit of the proposed explanations is that they permit the removal of qualifying terms which have frequently been applied to solonetzic soils in North America.

In the literature one sequence of solonetzic soil profiles has been frequently mentioned as being related to topography. This sequence of profiles has the solod member occurring in the lowest topographic position, usually in a depression, and with increasing elevation the solodized solonetz, solonetz and normal zonal soil are found in that order. This relationship between topography and solonetzic and related soils has been explained on the basis of differences in leaching as affected by topography. Moisture from run-off causes more leaching and consequently more solodization in and adjacent to the depression. This topographic relationship which has been described in many parts of the world occurs commonly in Saskatchewan.

In this paper data have been presented for solonetzic profiles whose sequence topographically is just the reverse of the classical sequence referred to in the foregoing. This second topographic sequence of solonetzic profiles occurs frequently in Saskatchewan, although the authors are not aware of it having been previously described in Saskatchewan or elsewhere. It appears that in the lowest topographic position a high water table or a local impermeability in the subsoil reduces leaching so that with increasing elevation progressively more leaching and solodization have occurred. It may be pointed out that the explanation of the origin of this second sequence of solonetzic profiles is also based on the concept that solodization results from leaching a solonized soil.

Data presented show that profiles from Site II definitely belong to the solonetzic group of intrazonal soils. In fact data presented show that there is more intense development of solonetzic and solodized characteristics in the profiles of Site II than in those of Site I. This statement is substantiated by both physical and chemical data. Solonetzic profiles at Site II show sharper differences between the A and B horizons than profiles of Site I for clay content, pH, base exchange capacity, exchangeable sodium and magnesium. Moreover, the profiles at Site II have a greater accumulation of base soluble silica than have the profiles at Site I. Since these characteristics as well as the morphological features evident in Figures 3, 4, 5, and 6 all point to intense solodization and solonization at Site II, there is no doubt that the profiles reported in this newly described topographic relationship have rightly been described as belonging to the solonetzic group of intrazonal soils.

While there is some difference in the intensity of development of solonetzic and solodic characteristics between the profiles of Site I and those of Site II, it should be pointed out that there is a very close correspondence between their general physical and chemical characteristics. For example, the morphological and chemical characteristics of the solodized solonetz profiles at the two locations are the same and show the same trends of change with varying stages of development. The solod profiles too show very similar characteristics. The difference in the topographic relationships at the two sites has not resulted in any differences in the characteristics of the various member profiles.

SUMMARY

The authors have reported data for 10 different profiles taken from two different sites in southeastern Saskatchewan. Eight of the ten profiles were classified as belonging to the solonetzic group of intrazonal soils. Material reported includes profile descriptions, soluble salts, exchangeable cations, total exchange capacity, base soluble silica, texture, pH and carbonate content.

1. In one of the locations sampled the sequence of profiles with increasing elevation as one proceeds away from a depression is solonetz, solodized solonetz, solod and normal zonal soil. So far as the authors are aware, this topographic sequence of profiles has not been described before. The relationship between profile members and topography in this case is just the reverse of the classically described relationship.

2. A high proportion of exchangeable magnesium in the clay-pan solonetzic upper B horizon has been found in all profiles possessing this clay-pan horizon.

3. Possible causes of the high proportion of exchangeable magnesium frequently found in the upper B horizon of solonetzic soils have been considered and an explanation has been proposed. It is pointed out that this explanation in no way alters any of the classical theories regarding the evolution of solonetzic soils.

4. The work reported here indicates that it would be most logical to classify solonetzic soils on the basis of their morphology.

5. A convenient method for leaching soils in the determination of exchangeable bases has been described.

6. The fact that exchangeable sodium may be removed from soil in highly significant amounts by leaching with water has been demonstrated.

ACKNOWLEDGMENT

The authors wish to acknowledge the help and co-operation received during the preparation of this paper from Dr. J. Mitchell, Soils Department, University of Saskatchewan, Messrs. H. C. Moss and J. S. Clayton of the Saskatchewan Soil Survey and Dr. J. M. MacGregor, Soils Division, University of Minnesota.

REFERENCES

1. Allan, J. A. Geology of Alberta soils. Dept. of Geology, University of Alberta. 1943.
2. Baver, L. D. Mechanical dispersion as an aid in the chemical study of soils. Jour. Amer. Soc. Agron. 20 : 403-410. 1928.
3. Breazeale, J. F. Magnesium and calcium in zeolitic soils. Arizona Agri. Expt. Sta. Tech. Bul. 26. 1929.
4. Chapman, H. D. and Kelley, W. P. The determination of replaceable bases and the base exchange capacity of soils. Soil Sci. 30 : 391-406. 1930.
5. Clarke, F. W. The Data of Geochemistry. Fifth Edition. Bul. 770, U.S.D.I. Govt. Printing Office, Washington. 1924.
6. de Sigmond, A. A. The Principles of Soil Science. Thomas Murby & Co. London. 1938.
7. Edwards, M. J. and Albleiter, J. K. Soil Survey of McKenzie Co. N.D., U.S.D.A. Bureau of Chem. and Soils, Series 1933, No. 37. 1942.
8. Ellis, J. H. and Caldwell, O. G. Magnesium clay solonetz. Trans. Third Intern. Cong. Soil Sci. 1 : 348-350. 1935.

9. GEDROIZ, K. K. The absorbing capacity of the soil and the zeolitic bases of the soil Zhwrnal Opitnoi Agronomii (J. Expt. Agron.) 17 : 472-527. (From collected mimeographed papers translated by S. A. Waksman, edited by C. A. Scofield. U.S.D.A. 1925). 1916.
10. GEDROIZ, K. K. The solodization of soils. Nossov. Agr. Expt. Sta., Bul. 44. (In Russian). (Quoted by Rost and Maehl (31)). 1926.
11. GLINKA, K. D. The great Soil Groups of the World. (Trans. by C. F. Marbut). Edwards Bros., Ann Arbor, Michigan.
12. GRACIE, D. S., RIZK, M., MOUKHTAR, A. and MOUSTAFA, A. H. I. The nature of soil deterioration in Egypt. Bul. 148, Ministry of Agric. Egypt. 1934.
13. JANZEN, W. K. A comparative study of the physical and chemical properties of Saskatchewan solonetzic and podsolic soils with particular reference to their clay fractions. Unpublished Master's thesis, University of Sask. 1941.
14. JOEL, A. H. The zonal sequence of soil profiles in Saskatchewan, Canada. Soil Sci. 36 : 173-187. 1933.
15. JOFFE, J. S. Pedology. Rutgers Univ. Press, New Brunswick, N.J. 1936.
16. KELLEY, W. P. So-called solonetz soils of California in their relation to alkali soils. Amer. Soil Survey Assoc. Bul. 15 : 45-52. 1934.
17. KELLOGG, C. E. Morphology and genesis of the solonetz soils of Western North Dakota. Soil Sci. 38 : 483-500. 1934.
18. KELLOGG, C. E. Development and significance of the great soil groups of the United States. U.S.D.A. Misc. Public. 229. 1936.
19. MACGREGOR, J. M. Studies on morphological solonetz soils of Alberta. Master's thesis. University of Alberta. 1938.
20. MACGREGOR, J. M. and WYATT, F. A. Studies on solonetz soils of Alberta. Soil Sci. 59 : 419-435. 1945.
21. MAEHL, K. A. Potentiometric determinations of exchangeable hydrogen in unsaturated soils. Ind. and Eng. Chem. Anal. Ed., 12 : 24-27. 1940.
22. MITCHELL, J., and RIECKEN, F. F. The chemical nature of some typical soil profiles of Saskatchewan, Canada. Sci. Agric. 18 : 109-119. 1937.
23. MITCHELL, J., MOSS, H. C., and CLAYTON, J. S. Soil Survey Report No. 12. Dept. of Soils, University of Saskatchewan. 1944.
24. NIKIFOROFF, C. C. Solonetz and solonchak soils of the Red River (Minn.-Dak.). Amer. Soil Survey Assoc. Bul. 11 : 141-150. 1930.
25. NIKIFOROFF, C. C. The Solonetz-like soils in South California. Jour. Amer. Soc. Agron. 29 : 781-797. 1937.
26. PANKOV, A. M. and SHAVRYGUIN, P. I. On the characteristics of the soil absorbing complex in the Manych River region. Trans. of the Dokuchaiev Soil Inst., Acad. of Sci. of the U.S.S.R. 9 : 205-235. 1934.
27. PEECH, MICHAEL. Determination of exchangeable bases in soils. Ind. Eng. Chem. Anal. Ed. 13 : 436-441. 1941.
28. RIECKEN, F. F. Some considerations in the magnesium cycle of weathering in solonetz soils. Proc. Soil Sci. Soc. Amer. 8 : 391-395. 1943.
29. ROBINSON, G. W. Soils, Their Origin, Constitution, and Classification. Second. Edition. Thomas Murby & Co. London. 1936.
30. ROST, C. O. Characteristics of some morphological solonetz soils of Minnesota. Jour. Amer. Soc. Agron. 28 : 92-105. 1936.
31. ROST, C. O., and MAEHL, K. A. Some solodized soils of the Red River Valley. Soil Sci. 55 : 301-312. 1943.
32. SCHOLLENBERGER, C. J., and DREIBELBIS, F. R. Analytical methods in base exchange investigations on soils. Soil Sci. 30 : 161-173. 1930.
33. SHAVRYGUIN, P. I. The effects of adsorbed magnesium upon the physical properties of soils. (In Russian) Pedology 2 : 167-173. (Quoted by Rost (30)). 1935.
34. SHUSKO, S. Y. The role of magnesium in the formation of solonetz properties in soils. Chem. Abst. 27 : 5458. 1935.
35. STALWICK, A. E. Comparative physical and chemical studies on some solonetz and non-solonetz soils of Saskatchewan, Canada. Unpublished Master's thesis, University of Sask. 1938.
36. STORIE, R. E. Profile studies of the solonetz soils of California. Amer. Soil Survey Assoc. Bul. 14 : 43-46. 1933.
37. SUSHKO, S. J. and SUSHKO, E. S. The influence of exchangeable magnesium upon the the dispersion and filterability of soils. (In Russian). Leningrad Acad. Sci., Gedroiz Sci. Inst. of Fert. and Soil Sci. 32 : 1-12. (Quoted by Rost (30)). 1934.
38. UVAROV, A. B. and KAMLOV, M. I. The relation of exchangeable magnesium to the physical properties of soils. (In Russian). Len. Acad. of Sci., Gedroiz Sci. Inst. of Fert. and Soil Sci. 34 : 13-17. (Quoted by Rost (30)). 1934.

OBSERVATIONS ON BUD BLIGHT OF SOYBEANS IN ONTARIO[1]

A. A. Hildebrand and L. W. Koch[2]

Dominion Laboratory of Plant Pathology, Harrow, Ontario

[Received for publication April 28, 1947]

As the acreage of soybeans in southwestern Ontario has increased rapidly during the past few years, so also has the number of diseases that affect this crop (4). One of the most potentially dangerous of these is bud blight or, as it has also been designated, top necrosis or streak. The first occurrence of this disease in the field was noted in Indiana in 1941 (13) and the following year it was found in Iowa (10) and in Ohio (6). Its discovery soon after in several additional States led Koehler (8) to comment in 1944 that, "In the Northern Mississippi Valley 'bud blight' appears to rival in importance the bacterial blights of which there are several."

Bud blight was first detected in Ontario early in July 1944 in the Harrow laboratory soybean experimental plots (2). Subsequently it has been found in so many widely-scattered commercial fields that its occurrence in Ontario, as in the more important soybean-growing areas in the United States, is probably co-extensive with the cultivation of this crop.

The inoculation experiments of Pierce (11) and of Johnson (6), as well as the observations of Samson (13) and Melhus (10), all indicated that bud blight is caused by a virus that belongs to the group of tobacco-ringspot viruses. Recently Allington (1) has definitely verified the identification of the virus. To date the only known means of transmitting the disease to susceptible hosts is by sap inoculation. Heretofore no one seems to have investigated the possibility of perpetuation and spread of the disease through seed from infected plants. This the present authors have attempted to do. The results of their experiments to date, together with a description of the disease as it manifests itself on the soybean in Ontario, form the content of the present paper.

SYMPTOMS OF BUD BLIGHT

In Ontario bud blight-infected plants have not been found earlier than the first week in July at which time, if they occur singly, they are much more difficult to detect than later in the season. This is due to the fact that the growth of plants following infection is usually arrested (Figure 1), and as a result they are frequently hidden by neighbouring healthy plants. It is the apical region of infected plants that attracts attention. The tip of the stalk with its terminal bud is curved in an unnatural manner. The terminal bud itself and others lower on the stalk, after first appearing flaccid, soon become brownish-discoloured and finally necrotic. The withered buds fall off at the slightest touch.

The petiole of the youngest trifoliate leaf, often thickened and shortened, may also be curved, thus accentuating the distortion of the tip region of the shoot. The leaflets are dwarfed and tend to be either cupped or rolled, the laminae at the same time showing a more or less rugose condition. In some cases a marked clearing of the veins has been noted in

[1] Contribution Number 906, Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.
[2] Associate Plant Pathologist and Pathologist-in-Charge, respectively.

FIGURE 1. Young naturally-infected plant showing arrested growth and buds in flaccid condition preceding wilting and necrosis.

FIGURE 2. Stalk of infected plant split longitudinally disclosing characteristic discoloration of pith of main stalk, lateral branch, and leaf petioles.

FIGURE 3. Pod cluster on infected plant showing external dark blotching and premature splitting-open of pods.

FIGURE 4. Blighted and prematurely defoliated shoot tip. Leaves still adhering show characteristic necrotic stippling.

transmitted light. In colour, the young leaflets are yellowish-green and often show necrotic stippling of the type shown in Figure 4. In common with other tissues of the shoot tip, the leaflets are brittle in texture and frequently fall prematurely (Figure 4). The symptoms observed on the tip leaves may also be noted on the second and third leaves but usually in less accentuated form. Discoloration of the older leaves culminates in an appearance of bronzing.

If, at the time buds or blossoms are dying, the stalk of an infected plant is split longitudinally, reddish-brown discolorations of the pith may often be noted in the vicinity of the nodes. In later stages of infection, the brownish discoloration is usually much more readily apparent and may involve internodal as well as nodal portions of the stem. Often, too, it extends into leaf petioles and lateral branches (Figure 2). Such, however, it not invariably the case, for, in the field examination of bud-blight plants, it has frequently been noted that, although the main stalk may show unmistakable symptoms of the disease, lateral branches arising from lower portions of the stalk appear to be perfectly healthy and capable of producing a full quota of apparently normal seed.

If infection takes place about blossoming time or a little later, many blossoms and young pod clusters wither and die. If pods are set, they are usually reduced both in number and size. Often the pods on an infected plant show a dark blotching and some will be found that have split open exposing immature and otherwise abnormal seeds (Figure 3).

In some instances seed produced by bud-blight plants may be indistinguishable from that derived from healthy plants, whereas in others it presents a most abnormal appearance. In regard to color, for example, some seeds remain green, others show a more or less marked brown streaking or marbling of the seed coat, and others may be almost black. Reduction in size, distortion of shape, wrinkling of the seed coat, "gaping" of the cotyledons and a withered appearance are other characteristics that may be noted in a collection of seed from bud-blight plants (Figure 5, A).

It is a further characteristic of bud-blight plants that they remain green in the fall long after healthy plants have reached full maturity. That is why it is easier to detect infected plants in the fall than earlier in the season. Mosaic plants show a similar tendency to remain green longer than healthy plants. The characteristic ladder-like brownish discoloration of the pith of plants infected with bud blight is an aid in distinguishing that disease from mosaic. In the opinion of the authors, bud blight was prevalent in Ontario prior to its recognition in 1944 and was probably confused with mosaic.

INCIDENCE OF BUD BLIGHT IN PLANT POPULATIONS ORIGINATING FROM SEED DERIVED FROM BUD-BLIGHT PLANTS

Since 1944, when bud blight was first detected in southwestern Ontario, the disease has never occurred in epiphytotic proportions. Nevertheless, each year, it has been observed throughout the whole district, infected plants ranging from a few in some fields to a maximum of about 3 per cent in others. Among diseased plants in many fields have been observed some which, apparently having become infected later in the growing season, were

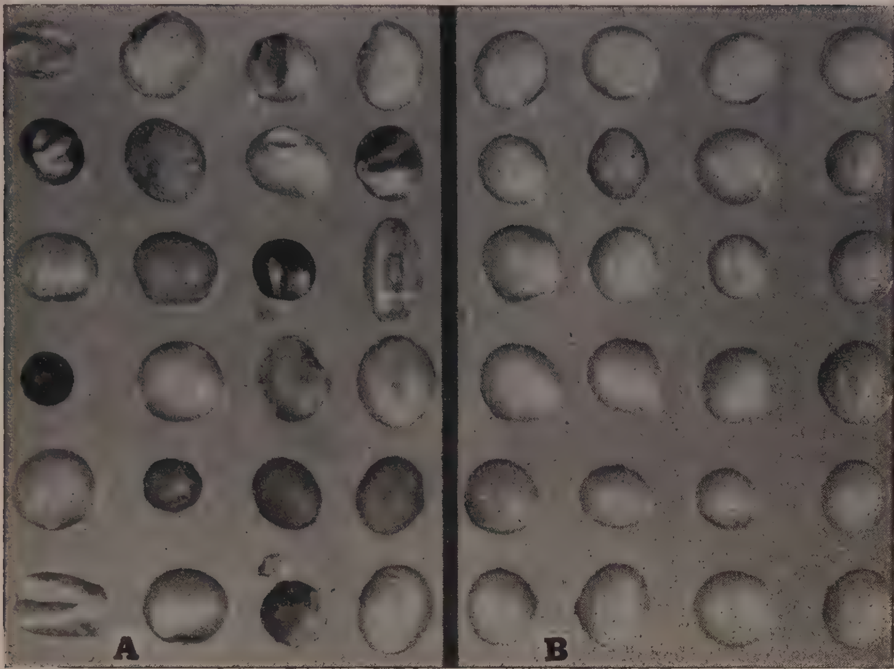

FIGURE 5. Contrast between seed obtained from bud-blight-infected (A) and from healthy (B) soybean plants, variety A. K. Harrow.

capable of producing viable seed. Whether such seed might afford a means by which the disease can be perpetuated and spread, posed a question that in the opinion of the authors should be answered. In an attempt to do so the experiments described below were carried out during the past two years.

(*a*) *Experiments in 1945*

From July to September 1944, bud-blight plants of the variety A. K. Harrow found in the laboratory plots and in nearby commercial fields, were marked in order that they could be readily located and examined periodically. As seed matured on at least a number of these plants, it was collected and, depending on whether it was obtained in close proximity to or at a remote distance from an unmistakably infected part of a plant, it was grouped as follows:

Category 1—Seed from pod clusters on portions of stalks showing characteristic brownish discoloration of pith.

Category 2—Seed from pod clusters on portions of stalks free from internal discoloration but in closest proximity to infected portions.

Category 3—Seeds from pod clusters on healthy-appearing lateral branches closest to main-stalk infected parts.

Category 4—Seeds from pod clusters on healthy-appearing lateral branches more remote from main-stalk infected parts.

The seed thus collected was stored over winter in a greenhouse potting shed, an environment that has been found especially conducive to high germination of soybean seed. On May 25, 1945, seed of each of the above

categories was planted by hand in 26-foot rows spaced 30 inches apart, in a randomized, five-replicate design, the rate of planting being 104 seeds per row. On June 15, three weeks after planting, emergence of seedlings was recorded and throughout the remainder of the season incidence of bud blight was carefully noted. Data in connection with these observations are summarized in Table 1.

TABLE 1.—EMERGENCE OF SEEDLINGS AND INCIDENCE OF BUD BLIGHT IN PLANTS FROM SEED PRODUCED AT DIFFERENT LOCATIONS ON BUD BLIGHT-INFECTED PLANTS RELATIVE TO INFECTED PARTS

Seed category	Number seed planted	Emergence		Incidence of bud blight	
		Number	Per cent	Number	Per cent
1*	520†	402†	77.3	5†	1.24
2	520	431	82.8	2	0.46
3	520	442	84.9	1	0.22
4	520	457	87.8	3	0.65
Totals	2080	1732	83.2	11	0.63

* For definition of categories, see above.
† Total for 5 replications.

Table 1 shows that emergence, which was lowest for seed in Category 1, showed a gradual increase as the source of seed became increasingly more remote from the visibly infected part. A difference between the germinating capacity of seeds in Category 1 and of those in the other three categories was expected because of the higher proportion of withered, dwarfed and otherwise abnormal-appearing seed (Figure 5, A) in the first-mentioned category.

Table 1 shows further that the highest incidence of bud blight, *i.e.*, 1.24%, occurred from seed in Category 1. Among the 1330 plants derived from seed in the other three categories, only 6 were infected, the latter representing a disease incidence of 0.45%. A ratio of almost 3 : 1 would suggest a possible correlation between the infective capacity of the seed and the place of origin of that seed on the plant in relation to apparent intensity of infection.

A disease incidence of only 1.24%, especially among plants derived from seed showing abnormalities as markedly as did many of those in Category 1, does not furnish too convincing evidence as to the seed-borne nature of the disease. This figure becomes somewhat more significant, however, when certain comparisons are made. For example, among a population of 24,164 plants in experimental plots contiguous to that in which the bud-blight test was being carried out, but planted with general-run seed of the variety A. K. Harrow, only 43 (0.17%) showed bud-blight infection.

(*b*) *Experiments in 1946*

Early in October 1945, seed was again collected from bud-blight infected plants of the variety A. K. Harrow. In every plant from which seed was taken, the presence of the disease, as suggested by external

symptoms, was verified by splitting the stalks and finding the characteristic brownish discoloration of the pith. This time, however, no attempt was made to group the seeds according to their location on the infected plants. The seed was stored, as during the preceding winter, in the laboratory greenhouse potting-shed. On May 14, 1946, this seed was planted by hand in twin, 30-foot rows spaced 30 inches apart, in a 5-replicate design, the rate of planting being 106 seeds per row. At the same time, in a number of contiguous plots in which other experiments were to be carried out, seed of the variety A. K. Harrow that had been produced the previous year in plots from which all bud-blight plants had been carefully and consistently rogued, was planted. It was considered, therefore, that the plants in these additional plots could be regarded as suitable checks for those in the bud-blight test. Throughout the season the incidence of bud blight in the plots was recorded, with results as indicated in Table 2.

TABLE 2.—INCIDENCE OF BUD BLIGHT IN PLANTS PRODUCED BY SEED FROM DISEASED AND FROM HEALTHY PLANTS

Seed from bud-blight-infected plants			Seed from bud-blight-free plants		
Number plants examined	Infected plants		Number plants examined	Infected plants	
	Number	Per cent		Number	Per cent
757	2	0.26	14,830	16	0.10

As Table 2 shows, only 0.26% of the 757 plants produced by seed from bud-blight plants were infected with the disease. This percentage is so low and is so slightly in excess of that among check plants, *i.e.*, 0.10%, that the evidence of seed-transmission of the disease is even less convincing in this second experiment than it was in the first.

Combining results for the two years, it will be noted that 13 (0.52%) of the 2489 plants derived from seed from bud-blight plants developed symptoms of the disease. At the same time, among 38,994 plants derived either from general-run seed or from seed obtained from bud-blight-free plants, 59 (0.15%) showed bud-blight infection.

DISCUSSION

At the outset of the present studies, it was realized that, as a rule, it is relatively rare for viruses to persist through the winter in true seed, and that the latter will usually give rise to virus-free plants though the parent plants were definitely infected. It was also known, however, that particularly in the Leguminosae, authentic cases of seed transmission of a number of virus diseases have been recorded, for example, mosaic of lima bean (9), mosaic of common bean (12), and mosaic of soybean (7). Moreover, the several accounts of the transmission of tobacco ring-spot virus through the seed either of tobacco (5, 14, 15), or of petunia (3), suggested that the virus which recently has become a threat of increasing importance to the soybean might be seed-transmitted. The present studies, undertaken to explore the latter possibility, have yielded results the significance

of which it is difficult to evaluate with certainty. The question as to the significance of the results centres around the fact that among plants grown from seed derived from carefully selected bud-blight-infected parent plants, the incidence of the disease has been low, the average not exceeding 0.52%. Whatever significance might seem to attach to this value *per se* is lost or at least greatly minimized by the fact that it does not exceed greatly 0.15%, the average for incidence of the disease among plants grown from seed derived from general-run and from bud-blight-free parent plants. In the light of these findings, it is difficult to avoid inclining to the view that bud blight of soybean is not transmitted through the seed.

SUMMARY

Bud blight, a potentially dangerous disease of soybeans caused by the tobacco ring-spot virus, is prevalent throughout the more important soybean growing areas of southwestern Ontario. The symptoms consist of a characteristic distortion, brittleness, and necrosis of the shoot tip, yellowish discoloration, more or less rugosity, cupping or rolling, sometimes vein-clearing, and necrotic stippling of young and bronzing of older leaves; blighting of buds and blossoms, and marked reduction in number and size of pods; frequent discoloration and malformation of seeds; characteristic reddish-brown discoloration of the pith, at first nodal, later internodal as well. Early-season infection arrests the growth of plants while late-season infection causes them to remain green until late in the fall.

In two years' experiments, 0.52% of 2489 plants grown from seed obtained from bud blight-infected plants developed symptoms of the disease while contemporaneously, among 38,994 plants grown either from general-run seed or from seed obtained from bud blight-free plants, 0.15% showed bud-blight infection. The above-mentioned percentages are so low, and the first is so slightly in excess of the latter, that what little evidence is adduced as to the seed-borne nature of the disease is of doubtful significance.

REFERENCES

1. Allington, W. B. Bud blight of soybean caused by the tobacco ring-spot virus. Phytopath. 36 : 319-322. 1946.
2. Conners, I. L. and D. B. O. Savile. Ann. Rept. Canadian Plant Dis. Surv. 24 (1944): 30-31. 1945.
3. Henderson, R. G. Transmission of tobacco ring-spot by seed of petunia. Phytopath. 21 : 225-229. 1931.
4. Hildebrand, A. A. and L. W. Koch. Soybean diseases in Ontario and effectiveness of seed treatment. Phytopath. 27 : 111-124. 1947.
5. Johnson, E. M. Virus diseases of tobacco in Kentucky. Kentucky Agr. Exp. Sta. Bull. 306. 1930.
6. Johnson, Folke. Soybean streak in Ohio. U.S. Dept. Agr., Pl. Ds. Rptr., 27 : 86-87. 1943.
7. Kendrick, J. B. and M. Gardner. Soybean mosaic: seed transmission and effect on yield. J. Agric. Res., 27 : 91-98. 1924.
8. Koehler, B. New developments in soybean disease studies. The Soybean Digest, 4 (8) : 6-7. 1944.
9. McClintock, J. A. Lima bean mosaic. (Abstr.) Phytopath. 7 : 60-61. 1917.

10. MELHUS, I. E. Soybean diseases in Iowa in 1942. U.S. Dept. Agr., Pl. Dis. Rptr., 26 : 431-432. 1942.

11. PIERCE, W. H. The identification of certain viruses affecting leguminous plants. J. Agric. Res., 51 : 1017-1039. 1935.

12. REDDICK, D., and V. B. STEWART. Transmission of the virus of bean mosaic in seed and observations on thermal death-point of seed and virus. Phytopath., 9 : 445-450. 1919.

13. SAMSON, R. W. Tobacco ring-spot on edible soybeans in Indiana in 1941. U.S. Dept. Agr., Pl. Dis. Rptr., 26 : 382. 1942.

14. VALLEAU, W. D. Seed transmission and sterility studies of two strains of tobacco ring-spot. Kentucky Agr. Exp. Sta. Bull. 327. 1932.

15. ———. Experimental production of symptoms in so-called recovered ring-spot tobacco plants and its bearing on acquired immunity. Phytopath., 31: 522-533. 1941.

VEGETATIVE CHARACTERS OF COMMON WESTERN WEED SEEDLINGS AS AN AID TO THEIR IDENTIFICATION

Archibald C. Budd

Dominion Experimental Station, Swift Current, Sask.

[Received for publication April 15, 1947]

The writer, when engaged in studies of the germination of weed seeds (1), found it desirable to prepare a table to facilitate the identification of weed seedlings in the cotyledon stage. It was found that practically no literature was available on this subject, although an excellent work, published during the last century by Sir John Lubbock (2), indicated the great possibilities for seedling identification of plants in general.

In order to make studies of seedlings, seeds of about 80 species of weeds were sown in three-inch and six-inch flower pots of sandy loam soil in the greenhouse of the Soil Research Laboratory at the Dominion Experimental Station, Swift Current. All seeds were sown quite shallow, the smaller ones being placed on the surface and covered with a light sprinkling of sand. In the case of a few large-seeded species, planting was done at depths up to one-quarter of an inch below the surface. As far as possible the soil was maintained at optimum moisture conditions and the greenhouse was warm, although the temperatures varied considerably.

In most cases, emergence was found to take place sooner than under field conditions. The favourable moisture and temperature conditions apparently had an effect on the length of time required for various seeds to germinate, and in many instances they did not approximate the times observed under field conditions in the weed nursery rows. In this nursery, weed seeds were sown under field conditions every fall for a number of years, notes being taken of the dates of emergence, flowering, maturity and of growth habits of the various species.

The earliest species to germinate in the greenhouse, as in the field, were Russian pigweed, purple cockle and the false flaxes. Indian mustard emerged one day before wild mustard and this was also consistent with behaviour noticed in the nursery rows. On the other hand, red-root pigweed and purslane were among the medium early species, earlier than wild buckwheat and villose bugseed which are both very early in the field. This was probably due to soil temperature, as red-root pigweed and purslane under field conditions do not germinate until the soil is quite warm, usually in June. Most of the weed seeds used were obtained from plants grown in the weed nursery rows which were used by the writer for study purposes, but a few were kindly sent from the Dominion Field Husbandry Division at Ottawa and the Department of Field Husbandry, University of Saskatchewan.

In the plates accompanying this article, all weed seedlings shown are magnified to 1.3 diameters. The numbers on the photos represent the reference number of the species as used during the weed seed experiments.

The results of the study are set out in the table which is largely self-explanatory, but a few notes may be helpful. There are only two fairly common western weeds with long, filiform cotyledons, namely, bugseed

and Russian thistle. The cotyledons of bugseed are a pale, flat green in colour while those of Russian thistle are dark green and shiny. Bugseed is not likely to be found except on sandy soils, but is often the first weed to colonize badly drifted areas in Southwestern Saskatchewan. Several reports of Russian thistle on badly drifted soils have been found to be based on bugseed.

Many of the common weeds, including almost all those belonging to the families *Chenopodiaceae* and *Amaranthaceae*, have small linear cotyledons and are rather difficult to differentiate under greenhouse conditions. Fortunately, under field conditions, the season of germination differs considerably. Lamb's quarters, summer cypress, Russian pigweed and spear-leaved goosefoot are very early, tumbleweed and prostrate amaranth considerably later, and red-root pigweed and purslane very late in germinating. Seedlings of summer cypress and Russian pigweed are similar, both being pale green in colour, but the coytledons of the latter are almost double the size of those of summer cypress.

It was noticed that the cotyledons of wild buckwheat grown in the greenhouse were often set at an angle of about 120 degrees instead of being opposite each other. The stem is a brighter crimson than in most seedlings.

Purple cockle and cow cockle seedlings are similar in size, shape and colour but may readily be distinguished by the conspicuous venation of the cotyledons of the latter. This is clearly shown in Figure 2. The seedlings of night-flowering catchfly and bladder campion are similar and both frequently have three cotyledons. This condition can occur in many plants (3) but apparently it is more common in these two weeds than in most species.

Evening primrose seedlings are very conspicuous and of a pleasing appearance with their pear-shaped cotyledons which are distinctly purplish towards the base.

Apparently all the members of the sub-family *Cichoriaceae* (*Liguliflorae*) of the *Compositae* have a single primary foliage leaf following the cotyledons instead of the usual pair of leaves. (Figure 4, *No*. 152). This trait, however, is found in a few other weed species amongst which are western dock, wild carrot, plantain and gumweed. The last named usually bear a very large single foliage leaf which is spatulate and stands erect.

This paper is submitted in the hope that it will be of use to workers in weed studies and that others will carry out further studies along this line and formulate a workable key for the identification of western weed seedlings.

SUMMARY

About 80 species of common Western Canadian weeds were grown at the Dominion Experimental Station, Swift Current, Sask., in order to study their vegetative characters. A summary of these characters is presented in tabular form, and their value for the identification of weed seedlings is discussed. Features by which certain groups of similar appearance may be distinguished are brought out in the text.

[Continued on page 332]

TABLE 1.—VEGETATIVE CHARACTERS OF WESTERN WEED SEEDLINGS

Name of species	Colour of stem	Cotyledons						Primary foliage leaves		
		Shape	Tips	Attach-ment	Length	Dorsal surface	Ventral surface	Shape	Surface	Remarks
					m.m					
Downy brome (*Bromus tectorum* L)	Green	Linear	Acute	S*	—	Pubescent	Green	Linear	Hirsute	
Wild oats (*Avena fatua* L)	Green	Linear	Acute	S*	—	Glabrous	Green	Linear	Slightly hirsute and ciliate	
Couch grass (*Agropyron repens* (L) Beauv.)	Slightly reddish	Linear	Acuminate	S*	—	Glabrous	Green	Linear	Glabrous	
Darnel (*Lolium rigidum* Guad.)	Reddish	Linear	Acuminate	S*	—	Glabrous	Green	Linear	Glabrous	
Green foxtail (*Setaria viridis* (L) Beauv.)	Faintly reddish	Lanceolate	Acute	S*	6	Glabrous	Green	Linear-lanceolate	Glabrous	
Western dock (*Rumex occidentalis* S. Wats.)	Reddish	Ovate	Obtuse	SS**	—	Glabrous	Green	Ovate	Glabrous	Single leaf
Lady's thumb (*Polygonum lapathifolium* L)	Reddish	Ovate	Acute	S*	—	Glabrous	Green	Linear	Glabrous	
Wild buckwheat (*Polygonum Convolvulus* L)	Crimson	Linear oblanceolate	Obtuse	S*	6	Glabrous	Green	Cordate	Glabrous	
Garden atriplex (*Atriplex hortensis* L)	Green becoming reddish	Long-oblong	Obtuse	S*	10	Glabrous	Green (reddish tinge)	—	—	
Hastate atriplex (*Atriplex. patula* L var. *hastata* (L) Gray)	Reddish	Linear	Obtuse	S*	8	Glabrous	Green	—	—	
Lambs' quarters (*Chenopodium album* L)	Red	Linear-oblong	Very obtuse	S*	7–9	Glaucous	Reddish	Ovate	Mealy	
Saline goosefoot (*Chenopodium salinum* Standl.)	Red	Linear-lanceolate	Obtuse	Pet.***	—	Glabrous	Reddish	Ovate	Glaucous	
Red goosefoot (*Chenopodium rubrum* L)	Red	Linear-oblong	Obtuse	SS**	—	Glabrous	Reddish	Ovate	Glabrous	
Spear-leaved goosefoot (*Monolepis Nuttalliana* (Schult) Greene)	Pink	Linear	Acute	S*	6–7	Glabrous	Reddish	—	—	Rosette
Villose bugseed (*Corispermum villosum* Rydb.)	Crimson	Filiform	Acute	S*	5–6	Glabrous	Green	Linear	Sparingly hirsute	Cuspidate
Summer cypress (*Kochia scoparia* Schrad.)	Red	Linear-oblong	Obtuse	S*	4–5	Glabrous	Reddish	Linear-obovate	—	Ciliate
Russian pigweed (*Axyris amaranthoides* L)	Red	Linear-oblong	Obtuse	S*	9	Glabrous	Green	Ovate	—	Ciliate
Russian thistle (*Salsola pestifer* A. Nels.)	Red	Filiform	Obtuse	S*	—	Glabrous shiny	Green	Filiform	Glabrous	Cuspidate

*S—Sessile. **SS—Subsessile. ***Pet.—Petioled.

(Table 1 continued on page 329)

FIGURE 1—Weed Seedlings × 1.3

No. 4 Couch grass
No. 6 Darnel
No. 10 Green foxtail
No. 29 Wild buckwheat
No. 38 Spear-leaved goosefoot
No. 40 Villose bugseed
No. 46 Red-root pigweed

FIGURE 2—Weed Seedlings × 1.3

No. 53 Purple cockle
No. 54 Night-flowering catchfly
No. 55 Bladder campion
No. 57 Cow cockle
No. 65 Perfoliate peppergrass
No. 66 Common peppergrass
No. 69 Common false-flax
No. 70 Round-seeded false-flax

FIGURE 3—Weed Seedlings × 1.3

No. 68 Shepherd's purse
No. 72 Ball mustard
No. 76 Tumbling mustard
No. 78 Flixweed
No. 80 Hare's ear mustard
No. 85 Wild mustard
No. 89 Spider-flower
No. 107 Wild carrot

FIGURE 4—Weed Seedlings × 1.3

No. 112 Field bindweed (two views)
No. 116 Blue-bur
No. 135 Wild sunflower
No. 152 Prickly lettuce in first foliage leaf
No. 153 Prickly lettuce
No. 154 Perennial sow-thistle
Lower left General view of seedling pots in greenhouse

TABLE 1.—VEGETATIVE CHARACTERS OF WESTERN WEED SEEDLINGS—*Continued*

Name of species	Colour of stem	Cotyledons						Primary foliage leaves		
		Shape	Tips	Attachment	Length	Dorsal surface	Ventral surface	Shape	Surface	Remarks
					m.m					
Red-root pigweed (*Amaranthus retroflexus* L)	Bright red	Linear-oblong	Obtuse	S*	3	Glabrous dark green to reddish	Reddish	Ovate	Hirsute	
Prostrate amaranth (*Amaranthus blitoides* S. Wats.)	Reddish	Linear-oblong	Obtuse	S*	4	Glabrous	Reddish	Spatulate	Glabrous	
Tumble weed (*Amaranthus graecizans* L)	Red	Linear-ovate	Acute	S*	3	Glabrous	Red	Ovate	Glabrous	
Purslane (*Portulaca oleracea* L)	Red	Linear-oblong	Obtuse	S*	1.5–2	Glabrous dark green to reddish	Red	Obovate	Glabrous	
Corn spurry (*Spergula arvensis* L)	Slightly reddish	Linear-filiform	Acute	S*	6–10	Glabrous	Green	Linear	Glabrous	
Night-flowering catchfly (*Silene noctiflora* L)	Green	Ovate	Obtuse	S*	5	Glabrous	Green	Obovate	—	Ciliate
Bladder campion (*Silene vulgaris* (Moench) Garcke)	Green	Ovate	Obtuse	S*	5	Glabrous	Green	Obovate	—	Ciliate
Purple cockle (*Agrostemma Githago* L)	Green	Ovate	Obtuse	S*	10	Glabrous	Green	Linear-obovate	—	Ciliate
Cow cockle (*Saponaria Vaccaria* L)	Green	Ovate	Obtuse	S*	10	Veined glabrous	Green	Linear	Glabrous	
Perfoliate peppergrass (*Lepidium perfoliatum* L)	Green	Oblanceolate	Acute	SS**	7–8	Glabrous	Green	Dissected	Glabrous	
Common peppergrass (*Lepidium densiflorum* Schrad.)	Green	Spatulate	Acute	SS**	4	Glabrous	Green	Obovate	Glabrous	
Stinkweed (*Thlaspi arvense* L)	Green	Short elliptical	Round	Pet.***	—	Glabrous	Green	Obovate	Glabrous	Rosette
Shepherd's purse (*Capsella Bursa-pastoris* (L) Medic.)	Green	Elliptical	Round	Pet.***	2–3	Glabrous	Green	Oval	Stellate hairs	
False flax (*Camelina sativa* (L) Crantz)	Green	Short elliptical	Retuse	Pet.***	5	Glabrous	Green	Obovate	Hirsute	Ciliate
Large-seeded false flax (*Camelina dentata* Pers.)	Green	Short elliptical	Retuse	Pet.***	6	Glabrous	Green	Some lobed obovate	Slightly hirsute	
Ball mustard (*Neslia paniculata* (L) Desv.)	Green	Orbicular	Retuse	Pet.***	6	Glabrous	Green	Obovate	Hirsute	Rosette
Tumbling mustard (*Sisymbrium altissimum* L)	Green	Orbicular	Obtuse	Pet.***	2	Glabrous	Green	Obovate	Slightly hirsute	

*S—Sessile. **SS—Subsessile. ***Pet.—Petioled.

(Table 1 continued on page 330)

TABLE 1.—VEGETATIVE CHARACTERS OF WESTERN WEED SEEDLINGS—*Concluded*

Name of species	Colour of stem	Cotyledons						Primary foliage leaves		
		Shape	Tips	Attach-ment	Length	Dorsal surface	Ventral surface	Shape	Surface	Remarks
					m.m					
Flixweed (*Descurainia pinnata* (Walt) Britt. var. *typica* Detling)	Green	Linear-ovate	Obtuse	Pet.***	2	Glabrous	Green	Pinnately lobed	Hirsute	Rosette
Hare's-ear mustard (*Conringia orientalis* (L) Dum.)	Green	Elliptical	Round	SS**	6	Glabrous	Green	Obovate	Glabrous	
Wormseed mustard (*Erysimum cheiranthoides*	Green	Elliptical	Truncate to retuse	SS**	1–2	Glabrous	Green	Obovate	Hirsute	
Wild mustard (*Brassica Kaber* (DC) Wheeler var. *pinnatifida* (Stokes) Wheeler)	Green	Orbicular	Obcordate	Pet.***	5–6	Glabrous	Green	Unevenly pinnately lobed	Ciliate	
Indian mustard (*Brassica juncea* (L) (Cosson)	Green	Orbicular	Obcordate	Pet.***	5–6	Glabrous	Green	Unevenly pinnately lobed	Ciliate	
Spider flower (*Cleome serrulata* Pursh.)	Green and red	Lance-linear	Obtuse	S*	10–12	Glabrous	Green	Trifoliate	Slightly ciliate	
Black medick (*Medicago lupulina* L)	Reddish	Elliptical	Round	S*	—	Glabrous	Green	Mucronate almost cordate	Sparingly hirsute	Single leaf
Ridge-seeded spurge (*Euphorbia glyptosperma* Engelm.)	Reddish	Elliptical	Obtuse	S*	—	Glabrous	Reddish	Broadly ovate	Glabrous	Slightly erose
Thyme-leaved spurge (*Euphorbia serpyllifolia* Pers.)	Green	Elliptical	Obtuse	S*	—	Glabrous	Green	Broadly ovate	Glabrous	Truncate erose, red midrib
Leafy spurge (*Euphorbia Esula* L)	Crimson	Linear-oblong	Obtuse	S*	—	Glabrous	Green	Elliptical	Glabrous	
Small-flowered mallow (*Malva parviflora* L)	Green	Cordate	Acute	Pet.***	—	Glabrous	Green	Orbicular cordate	Glabrous	Doubly crenate
Yellow evening primrose (*Oenothera strigosa* (Rydb.) Mack and Bush)	Reddish	—	Obtuse	Pet.***	—	Glabrous	Very slightly reddish	—	—	
Wild carrot (*Daucus carota* L)	Reddish	Linear	Acute	S*	5	Glabrous	Green	Biternate	Glabrous	
Silky milkweed (*Asclepias syriaca* L)	Green	Elliptical	Obtuse	S*	—	Glabrous	Green	Long ovate acute	Ciliate	Single leaf cuspidate
Showy milkweed (*Asclepias speciosa* Torr.)	Green	Elliptical	Round	S*	—	Glabrous	Green	Elliptical	Glabrous	

Field bindweed (*Convolvulus arvensis* L)	Reddish	Elliptical	Emarginate	Pet.***	7	Glabrous veined	Green slightly reddish tip	Broadly saggitate ovate	Glabrous	
Wild morning glory (*Convolvulus americanus* (Sims) Greene)	Greenish red	Roughly circular	Truncate	Pet.***	—	Glabrous	Green	Cordate	Glabrous	
Blue-bur (*Lappula echinata* Gilib.)	Green	Orbicular elliptical	Mucronate	S*	6	Hirsute	Green	Spatulate	Hirsute	
Cryptantha (*Cryptantha Fendleri* (A. Gray) Greene)	Green	Orbicular elliptical	Mucronate	S*	—	Silvery hirsute	Green	Cordate	Copiously hirsute	
Wild toadflax (*Linaria vulgaris* Mill.)	Green	Ovate	Acute	S*	—	Glabrous	Green	Ovate	Glabrous	
Common plantain (*Plantago major* L)	Green	Spatulate	Obtuse	SS**	—	Glabrous	Green	Oval	Very sparingly hirsute	Single leaf
Rid-grass plantain (*Plantago lanceolata* L)	Reddish	Filiform	Acute	S*	10	Glabrous	Green	Lanceolate	Glabrous	
False ragweed (*Iva xanthifolia* Nutt.)	Faintly reddish	Elliptical	Slightly mucronate	Pet.***	—	Glabrous	Green	Elliptical	Hirsute	
Common ragweed (*Ambrosia artemisiaefolia* A. Gray)	Reddish	Oval	Obtuse	SS**	5	Glabrous	Green	Roughly cuneate	Hirsute	Cleft
Cocklebur (*Xanthium echinatum* Murr.)	Reddish	Lanceolate	Acute	S*	—	Glabrous	Green	Oval	Ciliate	Glandular
Wavy-leaved thistle (*Cirsium undulatum* (Nutt.) Spreng.)	Green	Oval	Round	S*	—	Glabrous	Green	Oval	Glabrous	Spiny
Gumweed (*Grindelia perennis* A. Nels.)	Green	Spatulate	Round	Pet.***	—	Glabrous	Green	Spatulate	—	Erect single leaf
Sneezeweed (*Helenium autumnale* L var. *montanum* (Nutt.) Fern)	Green	Spatulate	Round	S*	—	Glabrous	Green	Spatulate	Ciliate	
King devil (*Hieracium floribundum* Wimm. and Grab.)	Green	Oval	Obtuse	S*	—	Glabrous	Green	Oval-obtuse	Sparingly hirsute	Single leaf
Yellow goatsbeard (*Tragopogon dubius* Scop.)	Green	Linear	Acuminate	SS**	—	Glabrous	Green	Linear	Slightly ciliolate, base hairy	Single leaf
Prickly lettuce (*Lactuca Scariola* L)	Green	Elliptical	Mucronate	SS**	6–7	Hirsute	Green	Obovate	Slightly hirsute and ciliate	Single leaf
Blue lettuce (*Lactuca pulchella* (Pursh) DC)	Green	Elliptical	Obtuse	S*	6	Glabrous	Green	Oval, round tip	Glabrous	Single leaf
Perennial sow-thistle (*Sonchus arvensis* L)	Green	Elliptical	Obtuse	S*	—	Glabrous	Green	Obovate	Glabrous	Single leaf

*S—Sessile. **SS—Subsessile. ***Pet.—Petioled.

ACKNOWLEDGMENTS

Acknowledgments are made to Dr. J. L. Doughty and Dr. W. S. Chepil of the Soil Research Laboratory at Swift Current, by whose permission these studies were carried out, and to Mr. E. W. Tisdale, Agrostologist, Dominion Experimental Station, Swift Current, for constructive criticism of the manuscript.

REFERENCES

1. Chepil, W. S. Germination of weed seeds. Sci. Agr. 26 : 307-357. July-August, 1946.
2. Lubbock, Sir John (Lord Avebury). On seedlings. 1892. London: Kegan Paul.
3. Brenchley, Winifred E. and Katherine Warington. The weed seed population of arable soil. III. The establishment of weed species after reduction by fallowing. Jour. Ecol. 24 : 499. 1936.

SELECTED LIST OF ACCESSIONS

MAIN LIBRARY
DEPT. OF AGRICULTURE
CONFEDERATION BUILDING,

BIBLIOTHEQUE CENTRALE
MINISTERE DE L'AGRICULTURE
EDIFICE DE LA CONFEDERATION

OTTAWA

Vol. 34, 1947. No. 5 July, 1947

When requesting publications, please give date of Selected List of Accessions, and number of publication on list.

1. Two blades of grass; a history of scientific developments in the U.S. Department of agriculture. T. Swann Harding. Norman, University of Oklahoma press, 1947. 352 p. pl.
2. Crops and tillage. J. C. Newsham. Third edition. London, Methuen & Co. ltd., 1947. 196 p. figs.
3. Farming and gardening for health or disease. Sir Albert Howard. London, Faber and Faber limited, 1946. 282 p. figs. pl. (This is published also in American edition under title: "The soil and health".)
4. Denmark. Copenhagen, Royal Danish ministry for foreign affairs and the Danish statistical department, 1947. 280 p.
   Contents: The Royal family; Land and people; The constitution; Education; Public finance; Agriculture; The fisheries; Handicrafts and industry; Trade and commerce; Financial institutions . . . Communications; Social conditions; Museums and scientific institutions; Economic conditions during the war. . . Danish science during the war, etc.
5. Writing scientific papers and reports. W. Paul Jones. Dubuque, Iowa, Wm. C. Brown Company, 1946. 115 p. (processed)
6. Filing agricultural bulletins. G. P. Scoville. Ithaca, 1945. 63 p. (processed) (Cornell university. Dept. of agricultural economics. A.E. 535)
7. Homes around the world. Harry L. Shapiro. New York, American museum of natural history, 1944-45. 30 p. il. (Man and nature publications. Science guide no. 124)

AGRICULTURAL CREDIT

8. France. Ministère de l'agriculture. Caisse nationale de crédit agricole. Rapport sur la situation du crédit agricole mutuel . . . 1946. Paris, (1947) 40 p.
9. Some social aspects of rural credit considered as problems of public policy. P.N. Driver. (In Bombay co-operative quarterly. Vol. XXX Serial no. 3. December, 1946. pp. 137-148)
10. Agricultural credit act, 1947. Dublin, Stationery office, 1947. 35 p. (Eire. No. 25b of 1946)

AGRICULTURAL ENGINEERING

11. Farm machinery in North America; a report submitted to the Ministry of agriculture and fisheries . . . London, H.M. Stationery office, 1946. 22 p. (Agriculture overseas. Report no. 3)
12. Milk and machinery. J. Matthews. (In Proceedings of the Institution of British agricultural engineers. Vol. IV. No. 1. January, 1947. pp. 1-11)
13. Poultry housing in Manitoba. J. R. Cavers and P. A. Kondra. Winnipeg, 1946. 15 p. figs. (Manitoba. Dept. of agriculture and immigration publication no. 205)
14. Brooder house and a range shelter. P.A. Kondra and G. C. Hodgson. Winnipeg, 1947. 8 p. figs. (Manitoba. Dept. of agriculture and immigration publication no. 212)
15. Mechanization in Canadian agriculture. (Reprinted from Agricultural institute review, March 1947)
16. The development of machinery for field drainage works. E. A. G. Johnson. (In Proceedings of the Institution of British agricultural engineers. Vol. IV, No. 2. April, 1947. pp. 13-34)
17. Harvesting with combines. W. M. Hurst and W. R. Humphries. Wash., 1947 (revision) 40 p. figs. (U.S. Dept. of agriculture. Farmers' bulletin no. 1761)

AGRICULTURAL ENGINEERING—Continued

18. Building a home freezer. F. S. Erdman. Ithaca, 1947. 30 p. figs. (Cornell university. State college of agriculture. Extension bulletin 705)
19. Six ways of haymaking . . . E. C. Ratcliff. (In Agriculture, May, 1947. pp. 63-67)
20. Insulation and ventilation of animal shelter buildings. D. M. Ryan and R. E. Pile. (Minnesota. University. Agricultural extension bulletin no. 253)
21. Push-button grain drying . . . one-man control and absence of dust features of new Oxford plant . . . (In The farmers weekly, May 2, 1947. p. 31)
22. An emergency homemade electric brooder. J. R. Tavernetti and others. Berkeley, California agricultural experiment station, n.d. 4 p. figs. (processed)
23. Farm buildings. (In Proceedings of the Institution of British agricultural engineers. Vol. III, No. 12. October, 1946. pp. 188-201)

AGRICULTURE—ECONOMIC ASPECTS

24. "The road ahead for agriculture". National farm institute ninth annual proceedings, 1947. Des Moines, Iowa, Chamber of commerce, 1947. 114 p.
25. Britain's new farm bill . . . L. F. Easterbrook. (In The land, Spring, 1947. pp. 92-4)
26. Farm economics, by C. S. Orwin. (In Journal of the Royal agricultural society of England. Vol. 107, 1946. pp. 31-37)

BEE CULTURE

27. Information about bee culture. Wash., 1947. 10 p. (processed) (U.S. Dept. of agriculture. Bureau of entomology and plant quarantine. E-276, revised)
28. Care of package bees in Alberta. W. G. le Maistre. Edmonton, 1947. 10 p. il. (Alberta. Dept. of agriculture bulletin no. 77)
29. Diseases and pests of bees. E. C. Martin. Winnipeg, 1947. 16 p. figs. (Manitoba. Dept. of agriculture and immigration publication no. 208)

BOTANY

30. Some mushrooms and other fungi of British Columbia. George A. Hardy. Victoria, King's printer, 1947. 96 p. il. (British Columbia provincial museum handbook no. 4)
31. A study of the genus paeonia. F. C. Stern. London, The Royal horticultural society, 1946. 155 p. il. pl. Bibliography: pp. 150-54.
32. Deux graminées nouvelles de l'Ungava (Canada). le Père Louis-Marie. La Trappe, Institut d'Oka, 1946. 23 p. figs. (Extrait de La revue d'Oka. Vol. XX, 114-124, 145-160, 1946) (Contribution no. 3)
33. "Over the garden wall". (An account of the history, lands and programme of the Royal botanical garden, Hamilton) Hamilton, Ontario, Royal botanical gardens, 1947. 12 p. map. (Special bulletin no. 1)
34. Sao Paulo. Secretaria da agricultura, industria e comercio. Instituto de botânica. Relatório annual, 1945. Sao Paulo, Brazil, 1946. 129 p. il. figs.
35. Distribution of the native grasses of California. Alan A. Beetle. (In Hilgardia. Vol. 17, no. 9. April, 1947. pp. 309-357)
36. Une voie nouvelle en biologie végétale: La culture des tissus. R. J. Gautheret. Paris, Librairie Gallimard, 1945. 202 p. figs. (L'Avenir de la science—21)

CHEMIC TECHNOLOGY

37. Utilization of seaweeds from the South Atlantic and Gulf Coasts for agar and its decomposition by bacteria. Durham, Duke university press, 1946. 80 p. figs. tabs. Literature cited: pp. 69-70. (Duke university marine station bulletin no. 3)
38. Tracer technique in wheat studies. Erwin Kreutzweiser. (In C-I-L oval, June, 1947. pp. 8-9)
39. Solvent extraction of oilseeds. W. H. Goss. Peoria, Northern regional research laboratory, 1947. 6 p. figs. (processed) (U.S. Dept. of agriculture. Bureau of agricultural and industrial chemistry. AIC-135)
40. Introduction to plastics. Denton D. McGrady. East Lansing, 1946. 47 p. figs. (Michigan state college. Engineering experiment station bulletin no. 104)

CONSERVATION OF RESOURCES

41. Minnesota. State dept. of conservation. Eighth biennial report, 1946. St. Paul, 1947. 326 p. il. tabs.

CO-OPERATION

42. Saskatchewan. Dept. of co-operation and co-operative development. Second annual report, 1946. Regina, King's printer, 1947. 87 p. tabs.
43. Consumers co-operative association. Eighteenth annual report, 1946. Kansas City, Mo., 1946. 24 p. il.

DAIRYING—DAIRY RESEARCH

44. British society of animal production. Report of proceedings, sixth meeting, 1946. General topic: The collection, interpretation and use of milk and butterfat records. Aberystwyth, The society, 1947. 50 p.
45. Studies on coliform organisms in dairy products: The practical significance of so-called heat resistant coliform organisms in the coliform testing of pasteurized milk, by L. Buchbinder and E. C. Alff. (In Journal of milk and food technology. Vol. 10, no. 3. May-June, 1947. pp. 137-148)
46. The keeping quality of pasteurized milk. A. C. Dahlberg. Ithaca, 1946. 23 p. figs. tabs. (Cornell university. Agricultural experiment station bulletin 838)
47. The utilization of buttermilk in New Zealand. F. H. McDowall. (In New Zealand journal of science and technology. Vol. 28, Sec. A. No. 2. August, 1946. pp. 97-132)

ECONOMICS

48. The scope and method of economics. O. Lange. (In The review of economic studies, 1945-6. Vol. 13, no. 33. pp. 19-32)
49. Profits and the ability to pay wages. F. R. Fairchild. Irvington-on-Hudson, New York, The foundation for economic education, inc., 1946. 64 p. (Popular essays on current problems. Vol. 1, no. 1, August 1946)
50. Statutes, orders, and official statements relating to Canadian war-time economic controls. Sheila I. Stewart. (Reprinted from the Canadian journal of economics and political science. Vol. 13, no. 1, February, 1947. pp. 99-114)

FEEDING AND FEEDING STUFFS

51. The golden anniversary of scientific feeding . . . Larry Wherry. (In Feedstuffs, April and May issues, 1947)
52. The use of soybeans in fattening rations for broilers and fryers. Rollin H. Thayer. (In Proceedings of the Oklahoma academy of science. Vol. XXVI, 1946. pp. 27-30)
53. The effects of feeding iodinated casein to laying hens . . . H. Temperton. (In Utility poultry journal, January, 1947. pp. 20-25)
54. Feeding experiments with growing and fattening pigs. J. P. Willman and F. B. Morrison. Ithaca, 1947. 56 p. figs. tabs. (Cornell university. Agricultural experiment station bulletin 836)
55. Scientific feeding methods now accepted policy in Canada . . . M. C. Herner. (In Canadian grain journal and monthly seedsman. Vol. 2, no. 11, June, 1947. p. 8)
56. Correct feeding practices essential for successful turkey production. S. S. Munro. (In Co-op chick news. June, 1947. pp. 7, 14)

FERTILIZERS

57. British views on fertiliser placement . . . F. Hanley. (In Farming, Jan.-Feb., 1947. pp. 165-168)
58. Koper als onmisbaar element voor plant en dier. W. J. Melchers en H. J. Gerritsen. Copper as indispensable element for plants and animals. Summary in English. Wageningen, N. V. Drukkerij "Vada," 1944. 56 p. figs.
59. Role of potash in growth and nutrition of Maryland tobacco. J. D. Bowling and D. E. Brown. Wash., 1947. 28 p. figs. tabs. (U.S. Dept. of agriculture technical bulletin 933)
60. Bibliography of literature on potash as a plant nutrient reviewed Sept. 1940 through Dec. 1940 . . . C. M. Schmidt and others. Wash., American potash institute, inc., 1947. 82, xxv p. (processed)

FOOD—FOOD PRESERVATION

61. Literature search on the preservation of food by freezing. B. H. Weil and Frances Sterne. Atlanta, 1946. 409 p. (processed) (Georgia school of technology. State engineering experiment station special report no. 23)
62. The Canadian committee on food preservation. Collected papers. Volume 3, 1944-1947. Ottawa, 1947. v.p.
63. Vegetable dehydration. London, H.M. Stationery office, 1946. 177 p. il. figs. tabs. References: pp. 175-177. [(Gt. Britain). Ministry of food. Scientific and technical series]
64. Conference on food acceptance research, 1945. Wash., 1946. 121 p. tabs. (U.S. War department. Office of the quartermaster general. Committee on food research. Quartermaster corps manual QMC 17-9)
65. Darkening of cooked potatoes can be reduced. [In Wisconsin university agricultural experiment station bulletin 471 (1947) pp. 37-8]
66. Don't guess. Buy by grade .... Ottawa, Dominion department of agriculture. Marketing service. Consumer section, (1947) 18 p. (In English and French)
67. Import requirements of the United States food, drug, and cosmetic act ... Wash., 1947. 51 p. (U.S. Federal security agency. Food and drug administration. Miscellaneous publication no. 2)
68. Handbook of food preparations. Revised. Wash., American home economics association, 1947. 47 p. tabs.
69. National live stock and meat board. 23rd annual report, 1945-1946. Chicago, 1946. 92 p. il.

FORESTS AND FORESTRY

70. Management control in selection forest. H. Knuchel. Oxford, Imperial forestry bureau, 1946. 32 p. figs. tabs. (Technical communication no. 5)
71. Dendrochronologies in Southwestern Canada. Edmund Schulman. (Tree-ring bulletin. Vol. 13, October, 1946—January, 1947. No. 2/3. pp. 10-24)
72. The TVA approach to forest development. Willis M. Baker. Durham, North Carolina, 1946. 15 p. (Duke university. School of forestry lectures no. 6)
73. Tables for estimating board-foot volume of timber. Clement Mesavage and J. W. Girard. Wash., U.S. Dept. of agriculture. Forest service, 1946. 94 p.
74. An introduction to the forests of Central and Southern Ethiopia. W. E. M. Logan. Oxford, Imperial forestry institute, 1946. 58 p. tabs. map. (Institute paper no. 24)
75. Christmas-tree farming. J. A. Cope. Ithaca, 1946. 32 p. figs. tabs. (Cornell extension bulletin 704)
76. The use of fire as a tool in the management of the brush ranges of California. H. L. Shantz. (Sacramento) California State department of natural resources. Division of forestry, 1947. 156 p. Literature cited: pp. 129-256.
77. Soil conservation tree nurseries. John W. Keller. (In Soil conservation. June-July, 1947. pp. 250-253)

GENETICS

77. Heredity and variation in micro-organisms. Cold Spring Harbor, L.I., The biological laboratory, 1946. 314 p. figs. tabs. References through the text. (Cold Spring Harbor symposia on quantitative biology. Volume XI)

GRAIN—MILLING

78. The history of the Quaker oats company Harrison John Thornton. Chicago, University of Chicago press, 1933. 279 p. il. Bibliography: pp. 258-267.
79. Farm storage problem—hot wheat ... (In GTA digest, June, 1947. pp. 12-13)
80. The milling industry of Peru ... J. A. Shellenberger. (In The Northwestern miller. Milling production section. May 13, 1947. pp. 3a, 18a-19a)
81. Composition of the wheat kernel. V. H. Morris and others. (In The Northwestern miller. Production section. May 13, 1947. pp. 4a-5a, 26a-30a)

HORTICULTURE

82. Vegetable growing. James Sheldon Shoemaker. New York, John Wiley and sons, inc., 1947. 506 p. figs. References: pp. 491-496.
83. Dwarf fruit trees for home gardens. I. B. Lucas. New York, A. T. De La Mare company, inc., 1946. 121 p. figs.

HORTICULTURE—Continued

84. American cranberry growers' association. Proceedings of the seventy-seventh annual meeting, 1947. Pemberton, N.J., 1947. 36 p.
85. Nut-growing. L. H. MacDaniels. Ithaca, 1946. 32 p. figs. (Cornell extension bulletin 701)
86. Table turnips (rutabagas) Staff members of the Ontario agricultural college. Toronto, 1947. 11 p. il. (Ontario. Dept. of agriculture bulletin 449)
87. Strawberry production in Oregon. G. F. Waldo and Henry Hartman. Corvallis, 1947. 27 p. figs. (Oregon state college. Agricultural experiment station bulletin 442)
88. Raspberry culture in Oregon. G. F. Waldo and Henry Hartman. Corvallis, 1947. 31 p. figs. (Oregon state college. Agricultural experiment station bulletin 443)
89. American society for horticultural science. Proceedings. Vol. 48. 1946. East Lansing, The society, 1946. 522 p. figs. tabs.
90. Delphinium. The book of The American delphinium society for 1946. (Highland Park, Illinois) (1947) 107 p. il.
91. Sunflower seed—the miracle food. J. I. Rodale. Emmaus, Pa., Organic gardening, 1945. 40 p. il. (Gardener's book club no. 5)
92. The quality of flower and vegetable seeds on sale in New York in 1946. A. B. Buchholz and M. T. Munn. Geneva, 1947. 69 p. (New York state agricultural experiment station bulletin no. 722)
93. The cultivation of medicinal plants. London, H.M. Stationery office, 1947. 24 p. (Gt. Britain. Ministry of agriculture and fisheries Bulletin no. 121).

INSECTS—INSECTICIDES

94. Destructive and useful insects; their habits and control. C. L. Metcalf and W. P. Flint. Second edition. New York, McGraw-Hill book company, inc., 1939. 981 p. figs. References through the text.
95. Migrations and breeding of the Red Locust (Nomadacris septemfasciata Serville) in Africa, 1927-1945. V. Morant. London, Anti-locust research centre, British museum (natural history), 1947. 60 p. figs. maps. Bibliography: pp. 41-45. (Anti-locust memoir 2)
96. Entomological society of Manitoba. Proceedings. Volume 2. No. 1. December, 1946. (Winnipeg) (1947) 50 p. (processed)
97. Observations on the morphology of the face in insects. E. M. DuPorte. (Reprint from Journal of Morphology. Vol. 79, no. 3, November, 1946. pp. 371-417)
98. Finnish entomological literature published in 1945 including economic entomology and control of insect pests. Helsinki, 1946. 17 p. (Annales entomologici Fennici. XII. 1, 1946. Appendix)
99. 2, 4-D as a weed killer. W. A. Harvey and W. W. Robbins. Berkeley, 1947. 8 p. (California agricultural extension service circular 133)
100. DDT and the balance of nature. V. B. Wigglesworth. (Reprinted from The Atlantic monthly, December, 1945. pp. 107-113)
101. The relative susceptibility of maize and wheaten products to invasion by the rust-red flour beetle, Tribolium castaneum Hbst. M. J. Oosthuizen. (Reprinted from The journal of the Entomological society of Southern Africa, Volume VIII, September, 1945. pp. 137-149)
102. Insect pests in Fiji. R. J. A. W. Lever. Suva, 1946. 36 p. figs. charts. (Fiji. Dept. of agriculture bulletin no. 23)
103. Seasonal breeding and migrations of the desert locust (Schistocerca gregaria Forskål) Z. Waloff. London, Anti-locust research centre. British museum, 1946. 74 p. maps. Bibliography: pp. 65-66. (Anti-locust memoir 1)
104. Equipment for the dispersal of DDT insecticides by means of aircraft. C. N. Husman and others. Wash., n.d. 17 p. figs. pl. (processed) (U.S. Dept. of agriculture. Bureau of entomology and plant quarantine. ET-228)
105. An annotated list of the butterflies of Jamaica. A. Avinoff and N. Shoumatoff. (In Annals of the Carnegie museum. Vol. XXX. art. XVI. 1946. pp. 263-295)

INSURANCE, AGRICULTURAL

106. Life insurance for farm families. Ralph R. Botts. Wash., 1947. 49 p. tabs. (U.S. Dept. of agriculture miscellaneous publication no. 621)
107. North Dakota. State hail insurance department. Twenty-eighth annual report, 1946. Bismarck, 1947. 64 p.

LIVE STOCK—BREEDING

108. Hormones in reproduction. S. R. Hall and J. F. Sykes. (In "Science in farming"—U.S. Department of agriculture. Yearbook of agriculture, 1943-1947)
109. History of the Holstein-Friesian breed in Canada. George Elmore Reaman. Toronto, Collins, 1946. 568 p. pl.
110. Raising turkeys, ducks, geese, game birds. Morley A. Jull. New York, 1947. 467 p. figs. tabs.

MARKETING—TRANSPORTATION

111. Wartime exports of Canadian farm products and post-war developments. Frank Shefrin. Ottawa, Dominion department of agriculture. Economics division, 1947. 44 p. tabs. (processed)
112. The wholesale market for fruits, vegetables, poultry, and eggs in New Haven, Conn. C. J. Otten. Wash., U.S. Dept. of agriculture. Production and marketing administration. Marketing facilities branch, 1946. 106 p. figs. tabs. (processed)
113. The use of surplus war cargo planes to transport agricultural perishables. R. W. Hoecker, R. K. Waldo and L. H. Brittin. Wash., The Edward S. Evans transportation research, 1945. 17 p. charts. (processed)
114. Flying perishables to market . . . J. L. Nicholson. (In Food industries. June, 1947. pp. 102-5)

114 (a). Business year book; a study of the Canadian market, domestic and export. 23d annual ed. Toronto, Maclean-Hunter pub. co. ltd., 160 p. il.

NUTRITION—VITAMINS

115. Food and health. Henry C. Sherman. New edition. New York, The Macmillan company, 1947. 290 p. Selected bibliography: pp. 261-290.
116. Recent advances in the chemistry of pectic substances. M. A. Joslyn and H. J. Phaff. (In Wallerstein laboratories communications. Vol. X, no. 29, April, 1947. pp. 39-56)
117. The nutritive value of meat extract. H. G. Rees and A. H. Salway. (In Chemistry and industry, May 31, 1947. no. 22. pp. 304-306)
118. The nutrition foundation, inc. Report of scientific director, 1946. New York, 1946. 81 p.

PASTURES—RANGES

119. Alfalfa improvement conference. Tenth report, Logan, Utah, 1946. Wash., U.S. Dept. of agriculture. Bureau of plant industry, soils, and agricultural engineering, (1947) 66 p. (processed)
120. Hydrologic aspects of burning brush and woodland-grass ranges in California. Frank Adams and others. (Sacramento) California state dept. of natural resources. Division of forestry, 1947. 84 p. figs.

PHYSIOLOGY

121. Annual review of physiology. Volume IX, 1947. Victor E. Hall, editor. Stanford university, Cal., Annual reviews, inc., 1947. 736 p. References at ends of chapters.
122. Recent progress in hormone research. Proceedings of the Laurentian hormone conference. Volume I. Edited by Gregory Pincus. New York, Academic press inc., 1947. 399 p. figs. References at ends of chapters.

PLANT BREEDING

123. The production of tobacco. Wightman W. Garner. Phila., The Blakiston company, 1946. 516 p. figs. tabs. Bibliography: pp. 487-502.
124. Harnessing the hormone: The use of growth regulating substances in gardens, fields and orchards. T. Swarbrick. London, Grower publications ltd., n.d. 52 p. figs.
125. Two new Illinois inbred lines of corn. R. W. Jugenheimer and others. Urbana, 1947. pp. 393-400. (Illinois. University. Agricultural experiment station bulletin 523)

PLANT BREEDING—Continued

126. Croissance des végétaux cultivés. Albert Demolon. Troisième édition. Paris, Dunod, 1946. 362 p. figs. pl.
127. Oats; variety and strain tests. Ottawa, 1947. 60 p. (processed) (Canada. Dept. of agriculture. Central experimental farm. Cereal division report no. 90)
128. Co-operative test of spring wheat varieties on Eastern branch farms and stations. Report, 1946. Ottawa, 1947. 10 p. (processed) (Canada. Dept. of agriculture. Central experimental farm. Cereal division report no. 86)
129. Observations sur les possibilités de culture du soja en Guinée forestière. R. Portères. Paris, 1946. 82 p. (France. Ministère de la France d'Outre Mer. Direction de l'agriculture de l'élevage et des forêts. Bulletin agronomique no. 1)
130. Sur la germination des graines de vanillier (Vanilla lanifolia And.) G. Bouriquet. (Bulletin de l'Académie Malgache. n.s. Tome XXV, 1942-1943. pp. 1-11)

PLANTS—DISEASES AND PESTS

131. The nature and prevention of the cereal rusts as exemplified in the leaf rust of wheat. K. Starr Chester. Waltham, Mass., Chronica botanica company, 1946. 269 p. figs. tabs. Bibliography: pp. 237-255. (Annales cryptogamici et phytopathologici. Volume IV)
132. Viruses and virus diseases of plants. Melville Thurston Cook. Minneapolis, Minn., Burgess publishing company, 1947. 244 p. (processed) Bibliography: pp. 196-234.
133. Antagonism between various micro-organisms and different species of the genus Pythium, parasitizing upon grasses and lucerne. A. Van Luijk. (Mededelingen van het phytopathologisch laboratorium "Willie Commelin Scholten" XIV. August, 1938. pp. 45-83)
134. Diseases of the raspberry. G. H. Berkeley and G. C. Chamberlain. Revised. Ottawa, 1947. 11 p. figs. (Canada. Dept. of agriculture publication 760, Farmers' bulletin 123)
135. A list of plant virus diseases in New Zealand. E. E. Chamberlain. (In New Zealand journal of science and technology, December, 1946. pp. 234-237)

RESEARCH

136. Inter-American institute of agricultural sciences. Third annual report, 1944-45. Wash., Pan-American union, n.d. 36 p. il.
137. Ontario research commission. Interim report, 1947. Toronto, King's printer, 1947. 152 p.
138. Research and scientific activity; Canadian federal expenditures 1938-1946. Ottawa, King's printer, 1947. 48 p. figs. tabs. At head of title: Department of reconstruction and supply.
139. The agricultural experiment stations of Japan. Tokyo, 1946. 92 p. figs. tabs. (Supreme commander for the allied powers. General headquarters. Natural resources. Natural resources section report no. 59)

RURAL SOCIOLOGY

140. Farm family living in the Prairie provinces. Florence M. Edwards. Ottawa, 1947. 28 p. figs. charts. (Canada. Dept. of Agriculture publication 787. Technical bulletin 57)
141. The population characteristics of New York state. W. A. Anderson. Ithaca, 1946. 87 p. tabs. (Cornell university. Agricultural experiment station bulletin 839)

TARIFF—TRADE

142. Trade agreement digests. Volume VII. Parts 1 and 2. Agricultural products and provisions. Wash., U.S. Tariff commission, 1946. 169, 207 p. (processed)
143. U.S. foreign trade in agricultural products by commodity and by country, annual fiscal year 1944-45 and 1945-46. Wash., U.S. Dept. of agriculture. Office of foreign agricultural relations, 1947. 37 p. (processed)

VETERINARY MEDICINE

144. Contagious pleuropneumonia of goats with special reference to immunization. H. S. Bawa. (In Indian journal of veterinary science and animal husbandry. Vol. XVI. pt. 1. March, 1946. pp. 1-10)

145. Method of controlling caecal coccidiosis of chicks. Division of animal pathology, Science service. Ottawa, 1947. 7 p. (Canada. Dept. of agriculture publication 788. Farmers' bulletin 141)

WEEDS

146. Blueberry weeds in Maine and their control. F. B. Chandler and I. C. Mason. Orono, 1946. 34 p. figs. (Maine. University. Agricultural experiment station bulletin 443)

147. Chemical weed control. H. E. Wood and P. J. Olson. Winnipeg, 1947. 15 p. il. (Manitoba. Dept. of agriculture and immigration publication no. 207)

ZOOLOGY

147. Life histories of North American jays, crows, and titmice . . . Arthur Cleveland Bent. Wash., Smithsonian institution, 1946. 495 p. pl. Literature cited: pp. 461-480. (United States national museum bulletin 191)

148. Property rights of animals. Nettie Bradford. Salt Lake City, 1946. 68 p. figs. Bibliography: pp. 51-68. (Bulletin of the university of Utah. Biological series. Vol. IX, no. 8)

New Periodicals in Library:

Journal of the British grasslands society. British grasslands society, Agricultural research building, Penglais, Aberystwyth, Cards.

Refrigeration abstracts. The American society of refrigerating engineers, 40 West 40th St., New York, N.Y.

Economic botany. The New York botanical garden, New York, 58.

The journal of general microbiology. British society for general microbiology, Cambridge university press, London, England.

The British journal of nutrition. British nutrition society, Cambridge university press, London, England.

L'Année biologique: Comptes rendus des travaux de biologie générale. Fédération des Sociétés de sciences naturelles, Paris, France.